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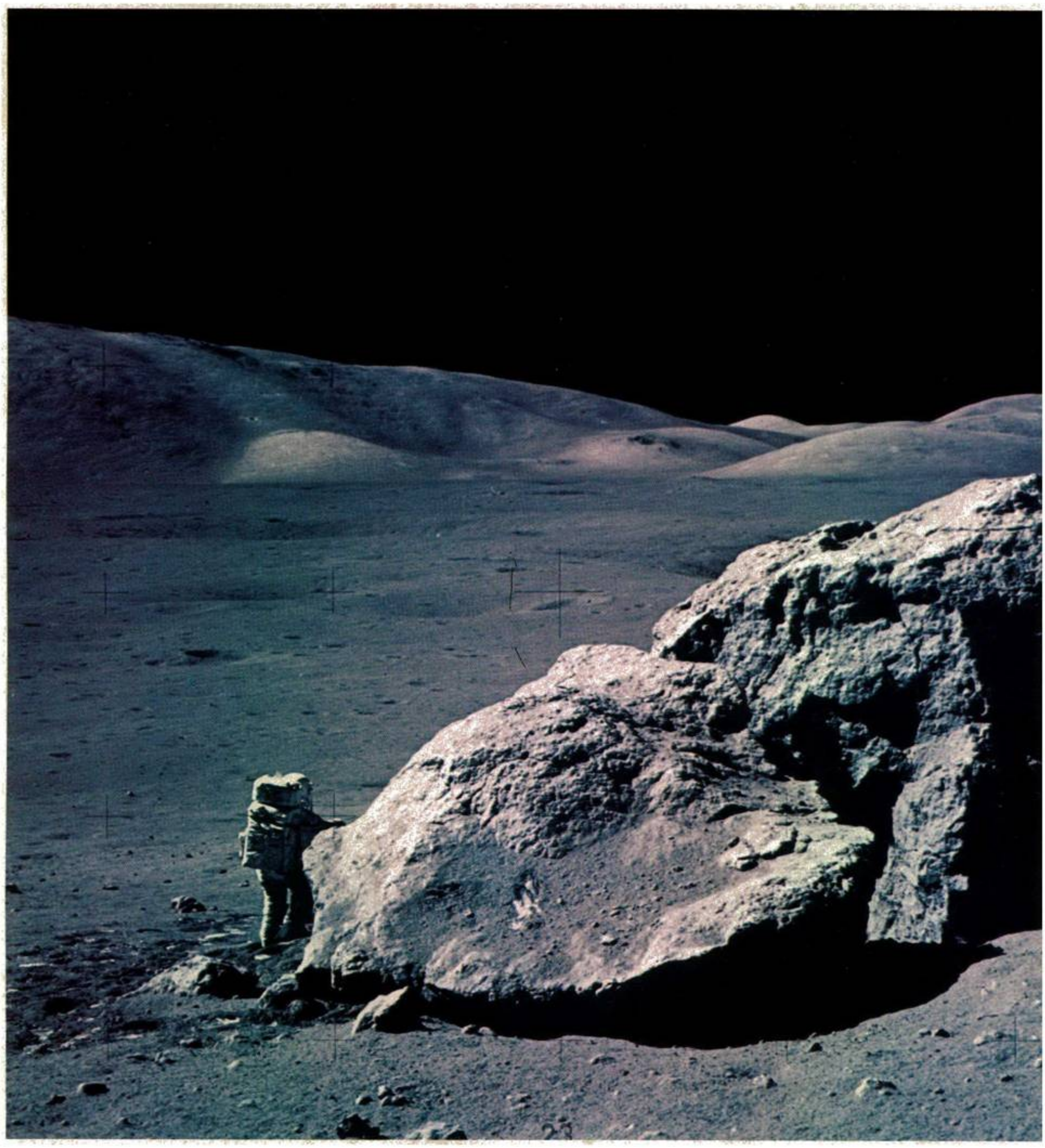

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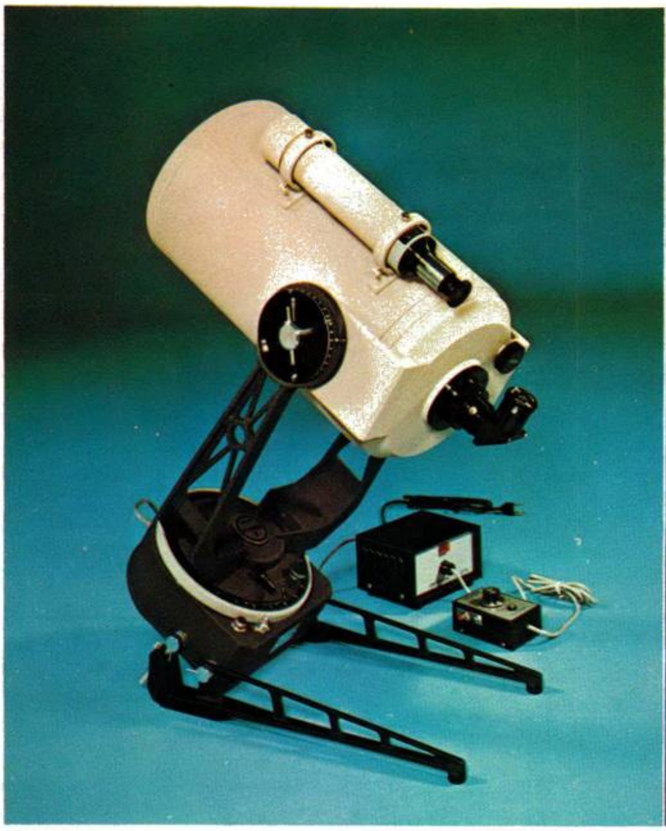

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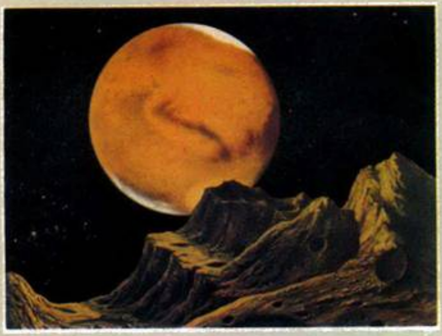
Reprints — Posters — Calendars

From ASTRONOMY

Mars as Seen From Deimos



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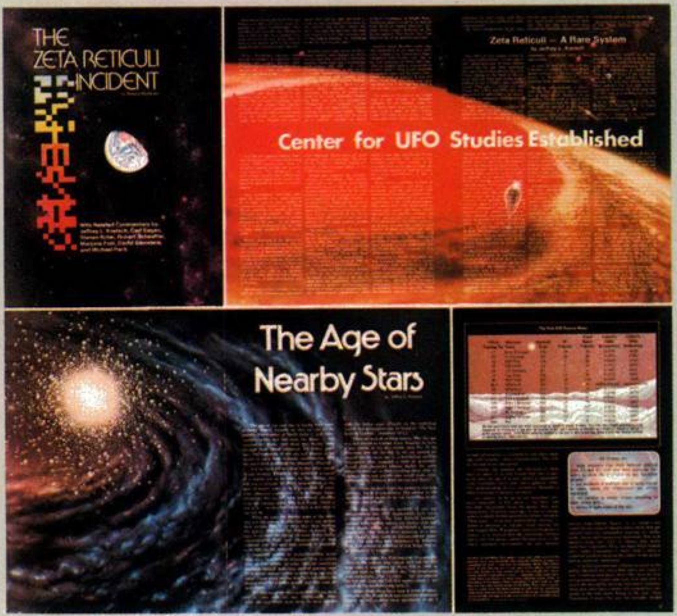
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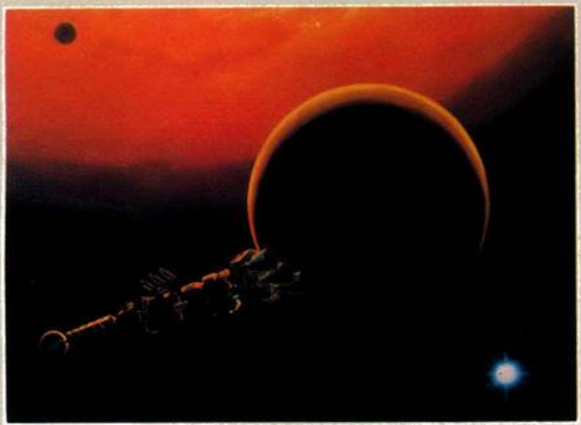

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ASTRONOMY

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September 1976
Vol. 4, No. 9

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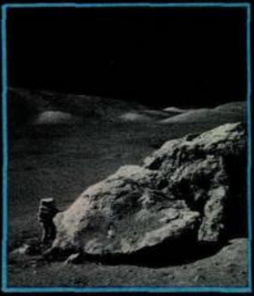

Cover

Seven years after men first walked on the moon, the drama and beauty of lunar exploration still remains. An Apollo 17 astronaut examines and collects samples from a boulder believed to have rolled — perhaps billions of years ago — from its perch high on the North Massif of the Taurus Littrow landing site. What has man learned from exploring the moon, and what does he know about its history and formation? This month ASTRONOMY reviews the ancient events of the moon's history, and what we know of them today. At this time, it is fitting that the planet Mars has become another object in the solar system examined intimately by human beings — this time through the robot eyes of the Viking lander. NASA photograph AS17-140-21497.

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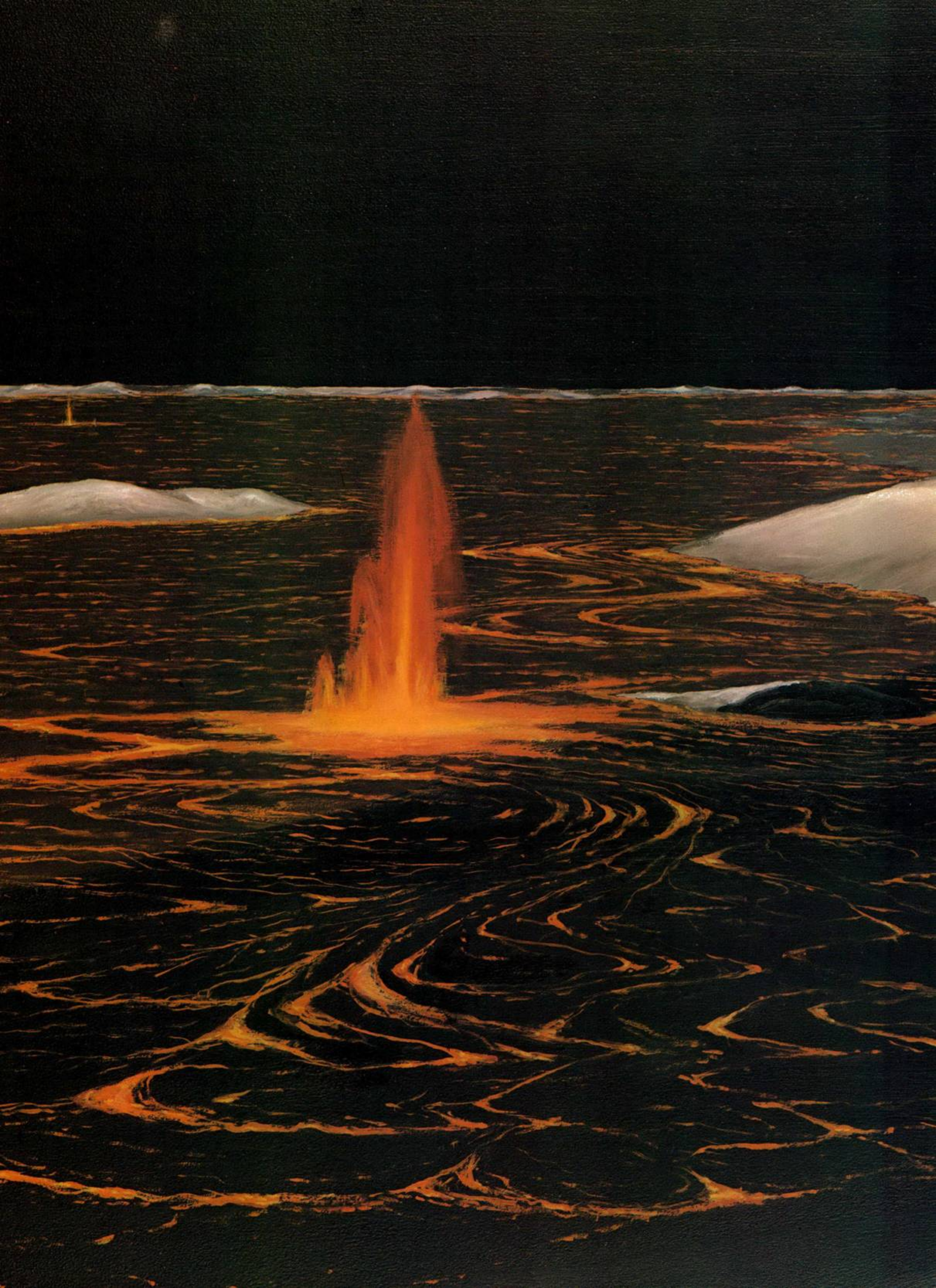
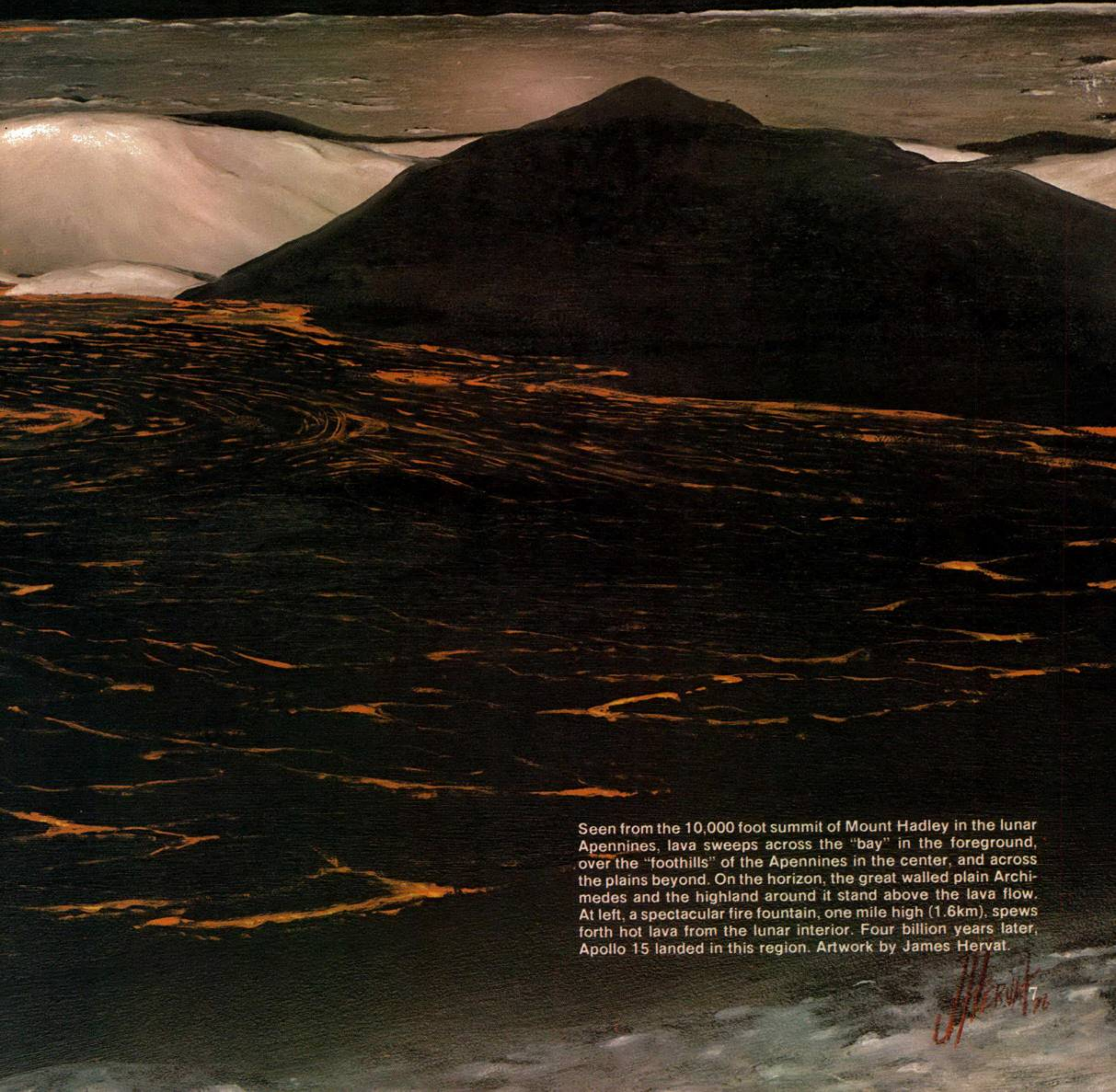
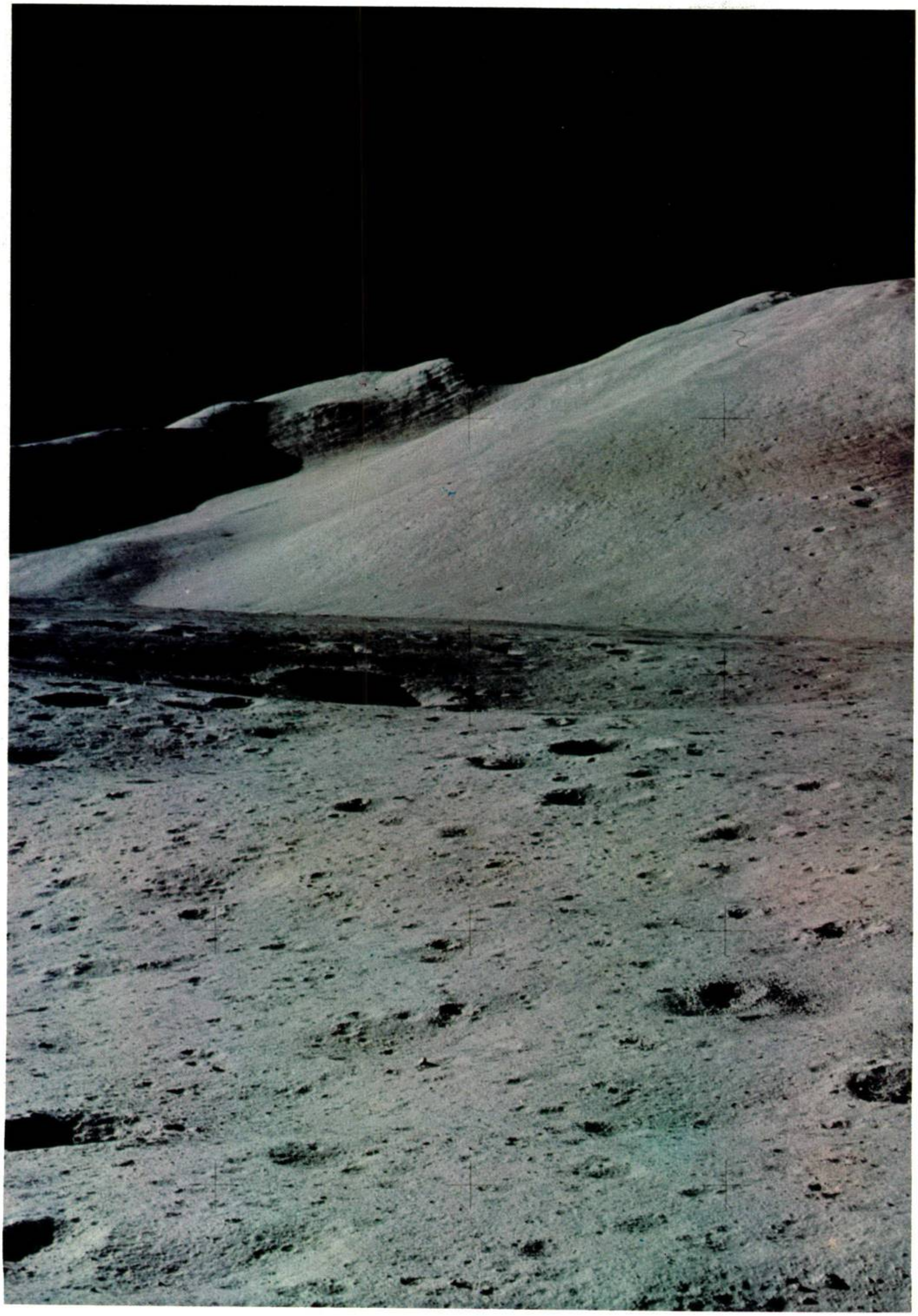


THE MOON'S EARLY HISTORY

by
William K. Hartmann



Seen from the 10,000 foot summit of Mount Hadley in the lunar Apennines, lava sweeps across the "bay" in the foreground, over the "foothills" of the Apennines in the center, and across the plains beyond. On the horizon, the great walled plain Archimedes and the highland around it stand above the lava flow. At left, a spectacular fire fountain, one mile high (1.6km), spews forth hot lava from the lunar interior. Four billion years later, Apollo 15 landed in this region. Artwork by James Hervat.



The moonscapes photographed by the astronauts all have something in common: They are stark, clean, beautiful — and incredibly still. If you watched for a billion years, nothing much would happen. A few rocks might roll down the hills. Micrometeorites would pit the rocks. A small meteorite might strike in the distance. Somewhere over the horizon a larger meteorite might hit the surface, blasting dust and rock into the sky. But such events would be few and far between.

It was different in the first billion years. Everything happened.

The moon's formation, crystallization of crustal rocks, excavation of giant basins, and flooding by vast sheets of lava, all happened between 4.6 eons (an eon is one billion years) and three eons ago, which we know from the ages of rocks brought back by the astronauts. By three eons ago, the moon looked pretty much as it does today, except for a few prominent craters such as Tycho and Copernicus, and their ray systems.

The best we can say about the formation of the moon is that it happened about 4.6 eons ago during a short interval of a few million years. This information comes from two sources. First, radioisotopic dating of meteorites indicates that they, or their parent materials, all formed at that time. Specialized techniques that measure so-called "formation intervals" indicate that the duration between formation of the first and last meteorites' parent bodies was no more than a few million years. Second, a few old specimens of lunar rock, studied by similar radioisotopic methods, indicate that the oldest parts of the moon's crust, or surface rock layers, formed at this time. These results are interpreted to mean that all the planets formed about 4.6 eons ago.

Data is much less clear about *how* the moon formed. We encounter more problems than facts, more controversies than conclusions. Contrary to the hopes of planetary scientists, the astronauts found very few rocks actually dating back to the beginning. A few rocks date from about 4.3 to 4.0 eons, but many more rocks date from between three and four eons. A major mystery, therefore, surrounds the moon's early days. To go back to the very beginning, we must rely heavily on theoretical conclusions drawn not only from lunar rocks, but also from meteorites and observations of other planets.

One of the main clues to the moon's origin, even before Apollo, has been its low density compared to Earth's. The values, determined by dividing a planet's mass by its volume, are 3.3 grams per cubic centimeter for the moon and 5.5 grams per cubic centimeter for Earth. For comparison, the density of water is one gram per cubic centimeter, and that of typical rocks is about three grams per cubic centimeter. The large difference between the average density of lunar material and that of Earth indicates that the moon contains different material than Earth. Probably the moon lacks the significant amounts of dense iron found at Earth's core.

This difference brought about the first theory of the moon's origin — the so-called *capture theory.* According to this theory, the moon formed in a different area of the solar system than Earth, which explains why it is made of different materials. The moon might have formed, for example, in a part of the solar system where less iron was available than near Earth. Later, it was somehow deflected from its original orbit and captured gravitationally by Earth. This theory could explain the moon's composition, but the problem of capture is a stumbling block; dynamics studies show the extreme unlikelihood of the moon's being captured intact if it approached Earth.

The second theory, called the *fission theory,* avoided this problem. The fission theory states that the original Earth was spinning so rapidly that surface materials were on the verge of flying off the equator. Some disturbance, such as tides raised by the sun, caused a portion of the planet to break off, forming the moon. This theory became somewhat more attractive when geologists realized that the breakoff might have occurred after Earth's iron drained to the center to form its core; material remaining at the surface would have been low density silicates. The moon, splitting away from Earth, would have formed from this material, explaining its low density. But here again, a major difficulty arose when dynamics studies showed that tides or other disturbances could hardly provide enough energy to raise all the lunar material entirely off of Earth.

Therefore, a third theory, called the *dual accretion theory*, became popular. According to this, the primeval Earth, as it was forming, involved two co-orbiting small masses. One of these might have been a passing planetoid captured in a cloud of material around the original body. Or, primeval Earth may have been a dual object from the beginning, like a binary star. In any case, each of the co-orbiting objects attracted material from the surrounding nebula, causing the growth of a planet-satellite pair. But, then, why should the moon, which in this theory was always near Earth, have formed with such a different composition?

Each of three main pre-Apollo theories seemed to have a fatal flaw. Some scientists were driven by frustration to facetiously suggest that perhaps the moon doesn't exist at all, since there seemed no way for it to have originated!

Undisturbed for eons, Hadley Delta was visited by Apollo 15 astronauts in 1971. The background mountain (Silver Spur) is about 12 miles (20km) distant. The steep cliff, which shows evidence of layering — perhaps lava flows — is about 1/2 mile (800m) high. NASA photograph AS15-87-11748. Readers may purchase copies of NASA photographs from Bara Photographic Inc., 4805 Frolich Lane, Hyattsville, Md. 20781; for $5 per 8x10 print, $9 per 11x14, or $1.50 per 35mm slide. Specify NASA photo number and include payment with order.

The Apollo flights, of course, aroused great hopes that the problem would finally be solved. However, since almost no returned rock samples dated from the very beginning, little direct evidence could be obtained from Apollo data. The best data was provided by study of the chemical composition of lunar material. An important clue in the interpretation of planetary chemistry is that, during igneous processes in molten rocks, different chemical elements tend to become associated in characteristic groups, often appearing in specific minerals and rocks. Four groups of elements are of special importance:

1) Lithophile elements are associated with low density, silica-rich minerals that rise to the top of a molten mass of planetary material (as slag floats in a smelter). Examples are silicon (Si), potassium (K), magnesium (Mg), aluminum (Al) and titanium (Ti).

2) Siderophile elements are associated with iron-rich minerals. The name comes from iron meteorites, once called siderites, or "star-stones". Examples are iron (Fe) and nickel (Ni).

3) Volatile elements are those with boiling points below about 2700 degrees Fahrenheit (1500 degrees Centigrade); they tend to evaporate easily if heating or melting occurs. Examples are hydrogen (H), helium (He), lead (Pb) and mercury (Hg).

4) Refractory elements have such high boiling points [above about 4500 degrees Fahrenheit (2500 degrees Centigrade)] that they concentrate in the last remaining minerals of a system subjected to very high temperatures. This group includes some lithophiles, such as aluminum and titanium.

Compared with Earth, the moon is rich in lithophiles and refractories, and poor in siderophiles and volatiles. This is simply another way of restating some now-familiar facts, such as the high abundance of aluminum and titanium in the first rocks brought back from the moon, and the utter absence of hydrogen-rich material such as water (H_2O) — although surface dust contains hydrogen absorbed from the solar wind. A closer look shows that the moon is low in elements that would have been driven off, and rich in elements that would have been left, if lunar material had once been very hot. Therefore, a likely interpretation made from lunar rock studies is that the moon formed from iron-poor material that was once heated to high temperature, driving off volatile gases and compounds, and leaving behind refractories.

Did these results clarify the origin of the moon at all? None of the three pre-Apollo theories seemed verified completely. The dynamical problem with the capture theory still existed. Chemical differences between rare elements on Earth and in the moon shed doubt on the idea that the moon had simply fissioned off of Earth. Dual accretion did not explain the different elemental patterns, even though the most recent results suggest that lunar composition is closer to Earth's than Apollo scientists had originally thought.

In short, scientists still have not solved the problem of where the moon came from. In recent years, however, there has been a drift toward various hybrid theories. For example, a kind of combination capture-fission theory suggests that Earth might have been hit by a massive interplanetary body, perhaps larger than the moon itself, blasting off a large amount of material from the outer terrestrial surface. This material would have been heated to high temperatures by the impact and pulverized into fine dust, allowing the volatile gases to escape immediately. Refractory (high temperature) elements would be enriched in such a dust-debris cloud.

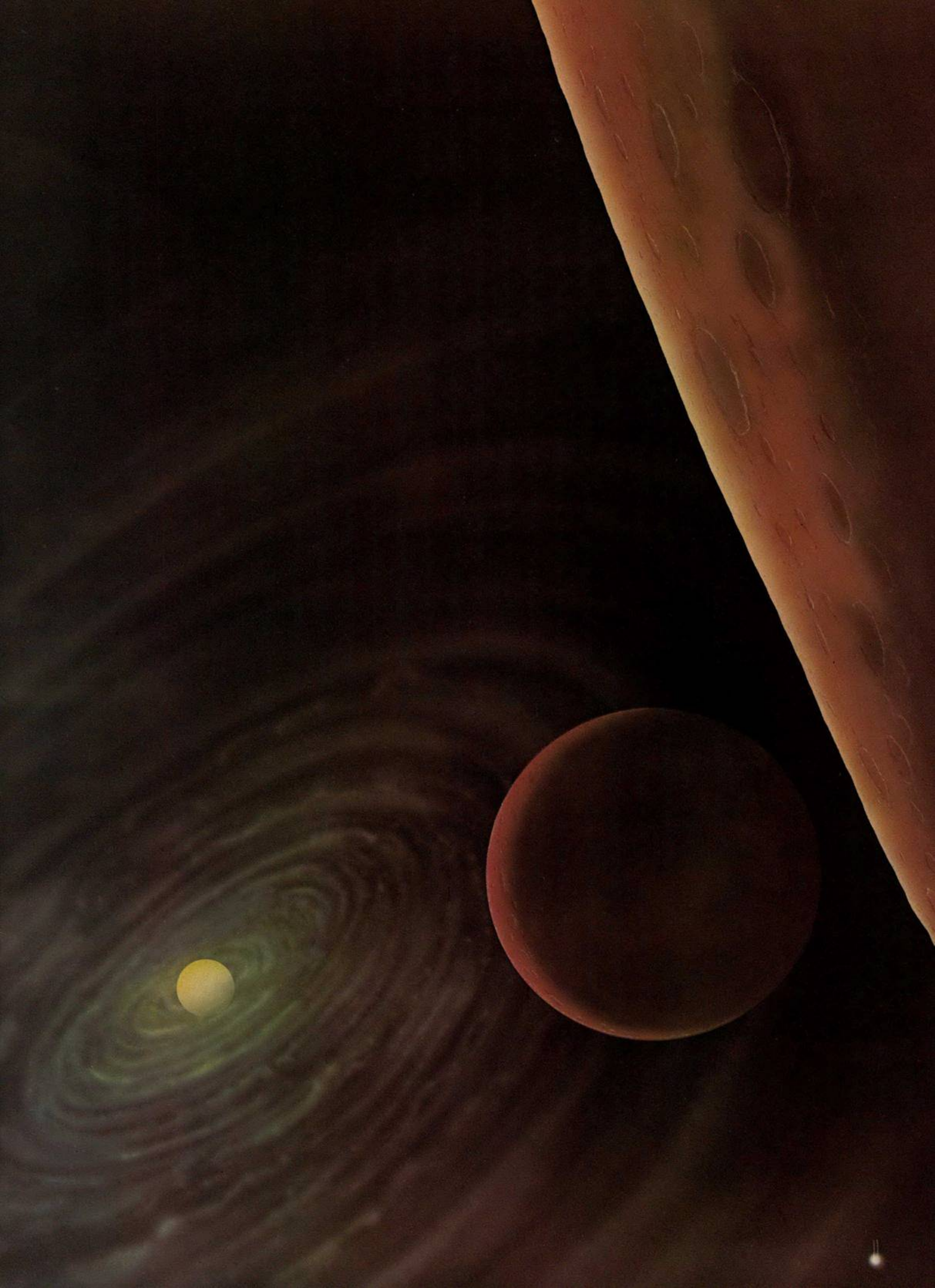
Another theory is a hybrid of the capture and dual-accretion ideas. A large body may have approached Earth, passing by after a near miss. As this body passed just above Earth's atmosphere, tidal forces could have torn it apart, producing a spray of asteroidlike debris and dust. Some of the larger blocks may have gone into orbit around Earth. Further accumulation of dust and condensation might have caused the largest piece to grow and sweep up the remaining fragments.

The interesting common thread running through these theories of lunar formation is that it was brought about by a cosmic accident, likely to happen to one of the nine planets but not to all nine. This helps explain a peculiar feature of the Earth-moon system: The two bodies are much more nearly the same size than any other planet-satellite pair. All other satellites comprise a much smaller fraction of their parent planet's mass.

This outgrowth of lunar theory can be applied to all the planets. If collisions or near collisions between planets and interplanetary debris were common in the early solar system, then each planet's final characteristics may have depended on a few large chance encounters — a concept that leads to a breakthrough in the general understanding of planet-satellite systems. If major chance events had *not* been important, then all planets should have evolved smoothly to produce similar appearing systems with similar inclinations, orbits and satellite systems. On the other hand, if catastrophic collisions were completely dominant, then planets' and satellites' characteristics should be totally randomized with wide variations in inclinations, orbits, etc.

But what we actually observe is an intermediate case. Planets tend to have small satellites and orbits with low eccentricities, but there are major

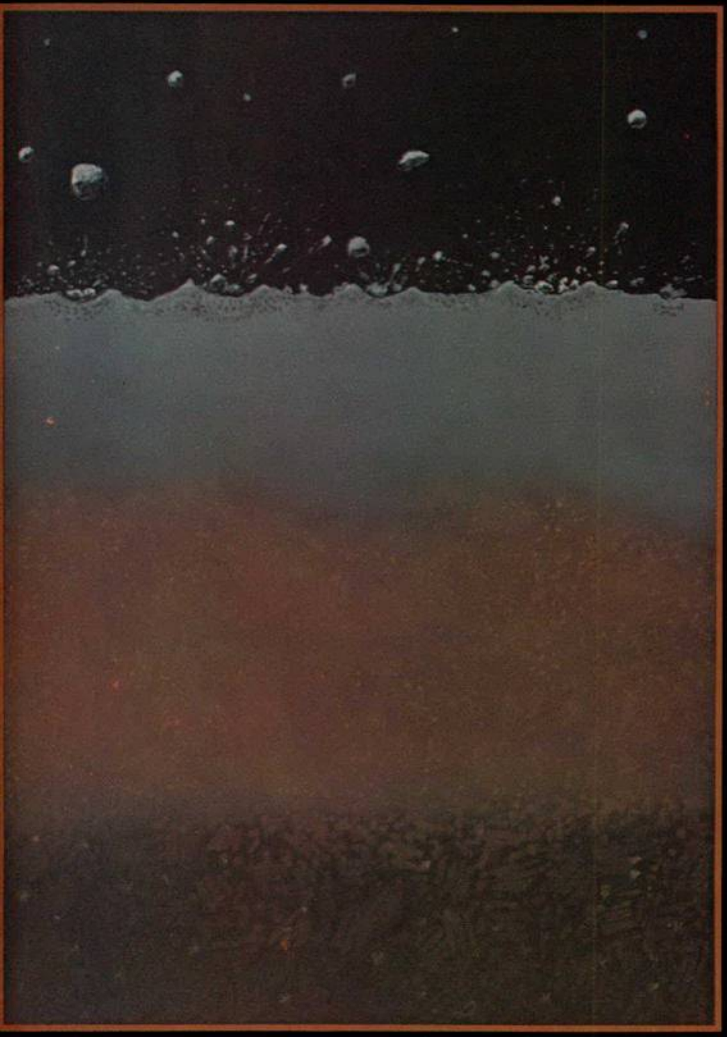
The dark side of the newly formed Earth glows with dull red heat from a vantage point in low orbit around Earth's satellite. The moon is also very hot; its surface glows from the impact heat of thousands of planetismals. Craters on both the moon and Earth — their heat-softened rock flowing under the pull of gravity — rapidly lose sharp relief. The sun, enveloped in gas, dust and rocky fragments, shines on this primitive scene. Artwork by Mark Paternostro.



Scenario for the Moon's Early History

Lunar history is not a series of catastrophic events that followed in numerical sequence, nor a result of strictly continuous ongoing processes. It is, however, a combination of processes and discrete events (such as the formation of mare basins) that left their mark on the moon.

Date (eons before present)	**Frame Number**	**Events**	**Evidence**
4.6		Origin of moon; possible collision of Earth with large interplanetary object.	Isotope measurements of lunar rocks and meteorites; bulk composition of moon.
4.6-4.5	1	Intense melting of outer layers of moon.	Isotope measurements of rocks from lunar highlands.
	2	Accumulation of anorthositic type rocks in upland crust.	
4.6-4.0	3	Intense bombardment of moon by interplanetary debris; intense cratering.	Crater counts; isotopic dating of rocks from various lunar provinces.
4.6-3.5		Moon moving away from Earth.	Direct observations; tidal theory.
4.3-3.9	4	Sporadic lava flows in upland areas and some large craters.	Recovery of few basaltic lavas from lunar uplands.
4.0-3.9?		One of the last of the most major impacts, forming Imbrium basin.	Isotopic dating of rocks from Imbrium ejecta.
3.9-3.2	5	Intensive lava flows partly filling some large basins and craters.	Recovery and dating of basalts from lunar maria.
3.0-0.0	6	Occasional large impacts forming large craters such as Copernicus, Aristarchus, Tycho.	Stratigraphic superposition, crater counts, isotopic dating of a few samples.



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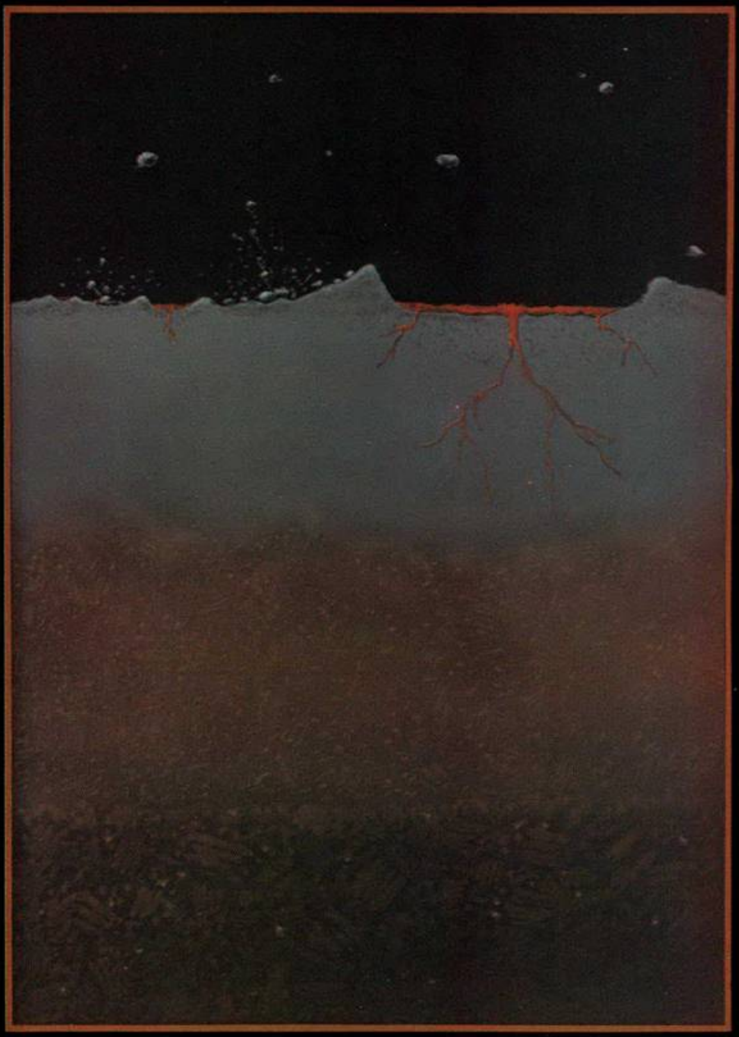

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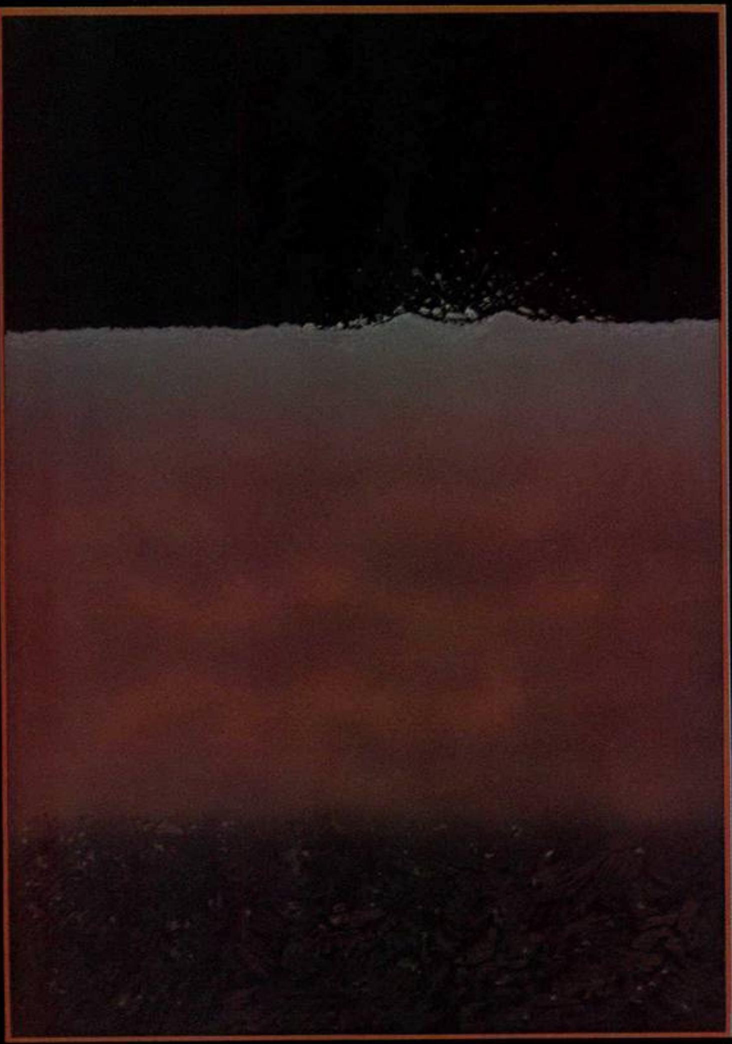

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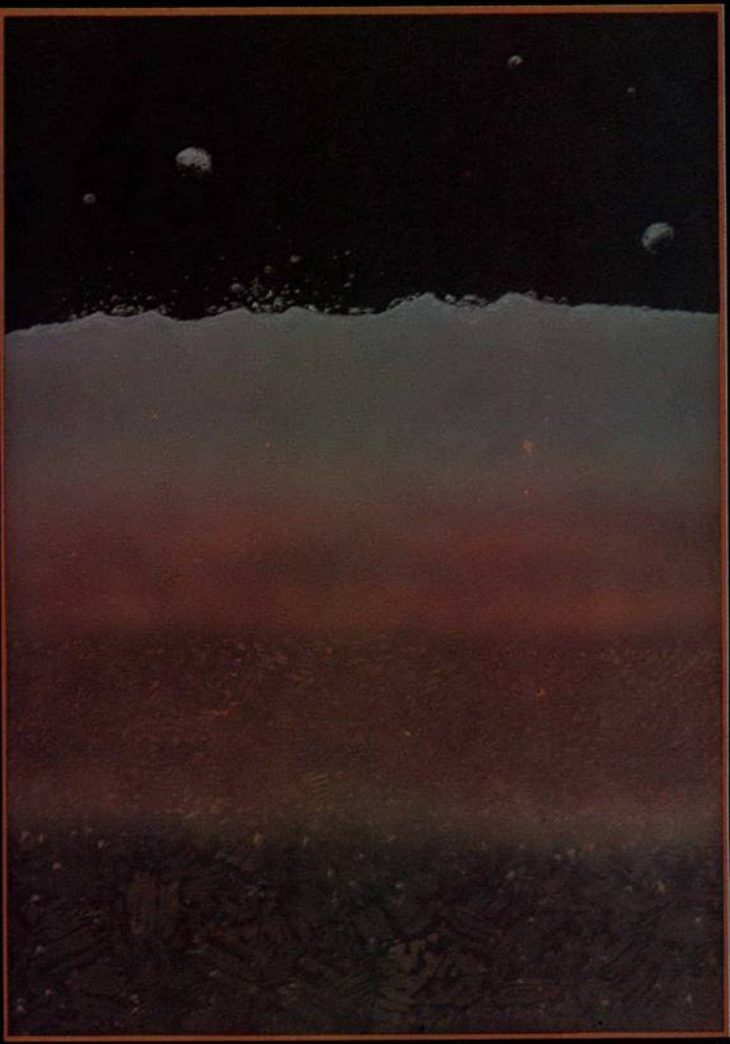

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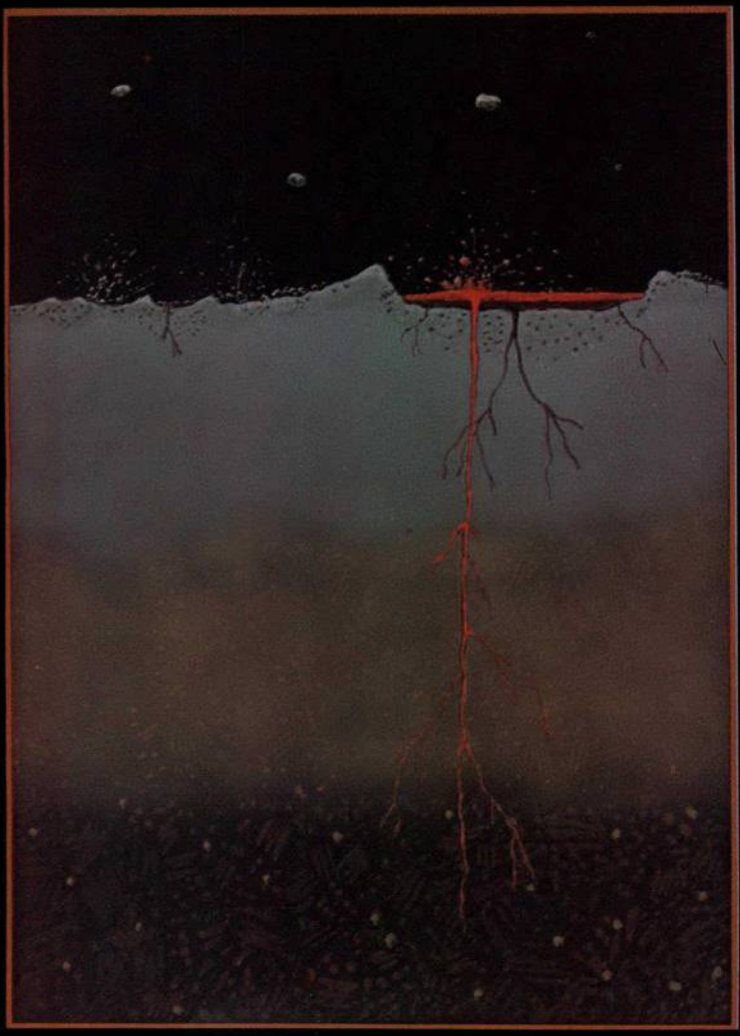

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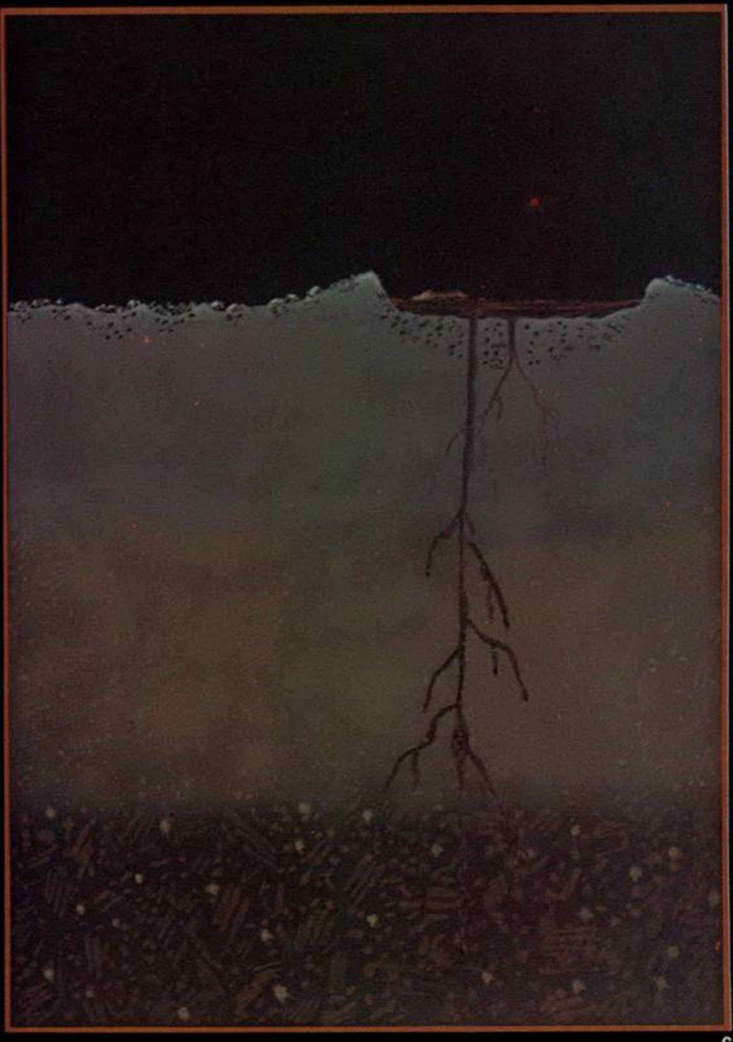

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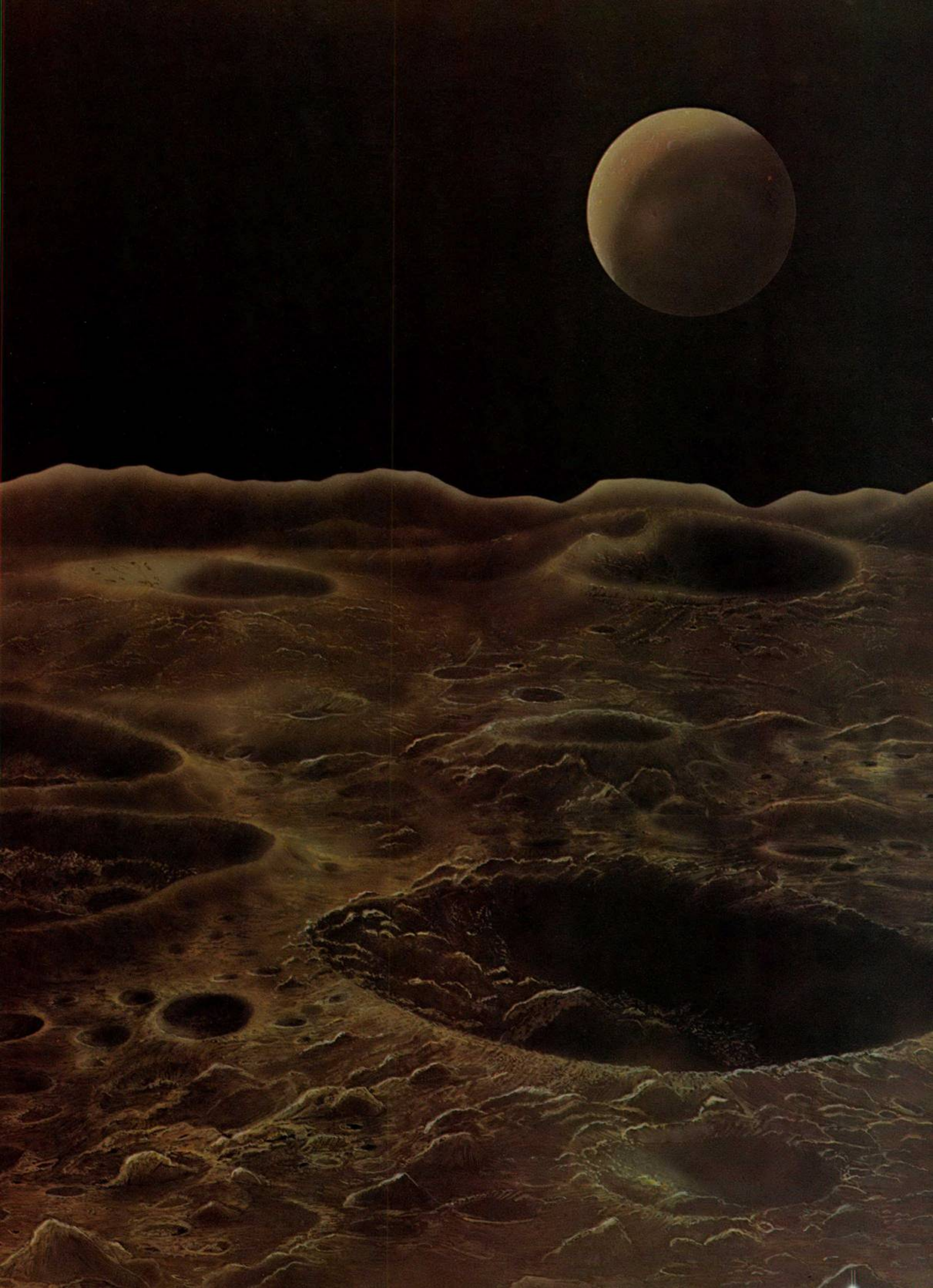

exceptions in each category. These exceptions may have been caused by a few large scale interactions between newly forming planets and the kind of interplanetary bodies hypothesized from studying the moon's early history. For example, the rings of Saturn might be the result of the planet's collision with a satellite. The high tilt of Uranus and Venus might have resulted from collisions between those planets and large interplanetary bodies. Thus the problem of the moon's origin, while not solved, has led to interesting new ideas about the origins of planet-satellite systems.

What happened on the moon after it formed? The answer is twofold: cratering and melting. The cratering process is directly related to the presence of many scattered interplanetary bodies — debris left over from planet formation. What direct information we have on the cratering process is derived from our knowledge of the dates of formation of certain lunar provinces (measured from rock samples returned by astronauts) and the number of craters formed in these different provinces (using lunar orbital photographs). The relation between these two figures gives the rate of cratering at different times in the moon's history. We can calculate the cratering rate at least as far back as four eons (the date of the oldest sites where the astronauts landed). The results show beyond doubt that the cratering rate four eons ago was hundreds or thousands of times higher than it is today. Probably in the first few hundred million years, from 4.6 to 4.4 eons ago, it was higher still — indicating a dense rain of giant meteorites striking the moon's surface. At the very beginning, large craters the size of Tycho or Copernicus may have been created every thousand years or so; several craters, a kilometer across, formed every year, and a crater as big as a football stadium formed practically every day.

Investigation of lunar rocks, as well as telescopic studies, indicates that these craters formed in explosions caused by impacts of giant interplanetary bodies ranging in diameter up to at least 100 miles. These bodies must obviously have been the last stragglers among the material that formed the planets themselves.

If crater-forming had been the only on-going process in the moon's early days, the entire surface today would look like the densely cratered uplands near Tycho or on the farside, and the composition of lunar rocks would be uniformly the same as the bulk composition of the whole moon. However, neither of these conditions is true, because a second process was occurring inside the moon during the first half eon — probably within the first 100 million years (4.6 to 4.5 eons ago). This process was a heating so intense that apparently much of the moon's outer layer, to a depth of at least several hundred kilometers, melted. In its earliest days, the moon probably resembled a vast smelting pot, in which heavier rocks sank to lower depths, while lighter materials floated to the surface. Among these lightweight materials were the moderately light colored minerals that coagulated and formed rocks known as anorthosites or anorthositic gabbros. After floating to the surface, accumulating into rocks and solidifying, they formed what has come to be known as the moon's anorthositic crust. Apollo seismic data indicates this crust is about 37-1/4 miles (60km) deep. Fragments of these rocks were brought back by the astronauts from the older regions of the moon's surface (or as chips blown by meteorite impacts from the older regions into the younger).

From the floor of the Imbrium basin, its distant walls form the horizon. This site will be flooded when the Mare Imbrium lavas flow across the surface. Earth — also a young and cooling object — hangs large in the lunar sky; it was much closer to the moon in their early days. Billions of years later, transformed by life processes, Earth would acquire its present-day blue and green tones. Artwork by Mark Paternostro.

From the point of view of geology and planetary appearance, the important fact is not *how* the early heating came about, but simply that it *did* occur and parts of the moon's interior melted. As a consequence, lightweight and lighter colored minerals floated to the surface, cooled and formed a rocky crust. Obviously, there was competition between the crust forming process producing smooth plains, and the external cratering, which would tend to produce chaotic, jumbled cratered topography. It seems clear that the cratering process must have won the race. The oldest regions known appear to be a chaos of one crater superimposed upon another. We can imagine, for example, that a large solidifying plain or lava flow would have survived only a few tens of millions of years before being blasted into a cratered topography indistinguishable from surrounding older provinces. On the other hand, the cratering rate was certainly declining by four eons ago (the date of the earliest "hard" data), and the decline continued until the cratering rate reached its present value about three eons ago. These lower bombardment rates were not sufficient to destroy any lunar plains that were formed after about four eons ago.

This suggests a possible explanation of a problem that has puzzled lunar scientists: Why does there seem to be a sharp cutoff in the numbers of rocks older than four eons? The explanation suggested by the above data is that the bombardment before four eons ago was so intense that it quickly pulverized rock units formed at that time. For example, a 100 foot thick lava flow formed at 4.2 eons may have been ground to dust for 4.1 eons, while a similar flow formed at 3.5 eons might have survived to the present. Other ancient rocks may have been buried and hidden under layers of debris blasted out of the larger craters. Judging by lunar rock dates and crater counts, the period from 4.6 to about 3.9 eons saw formation of the largest basins, such as Imbrium, Nectaris and Orientale, involving impacts of meteorites more than 100 miles in diameter according to calculation of the energy needed. The impacts and resultant explosions blasted thick layers of debris over much of the moon. Studies of these "ejecta blankets" reveal that turbulent mixtures of dust, gas and boulders swept across hundreds of kilometers of lunar surface within minutes after impact. Furthermore, blocks of rubble ejected at high angles fell back onto the moon, creating thousands of secondary craters within a few minutes of each major impact. Perhaps the sudden deposition of these ejecta blankets masked older rock units in many areas of the moon.

This explanation has not satisfied all lunar rock investigators. Some believe that a more sudden or catastrophic event must have occurred in order to destroy most of the lunar materials older than four eons. An interesting hypothesis states that a planetary catastrophe occurred four eons ago — a sudden but short-lived increase in bombardment of the surface (tantamount to saying that a sudden supply of meteorites appeared upon the scene). According to some investigators, this burst of meteorites could have been produced if a large interplanetary body that formed in the outer solar system was deflected into the inner solar system (by a near encounter with Uranus, for example). Such a body may have had another near encounter with one of the terrestrial planets — possibly Earth — causing it to fragment due to tidal forces. This would produce a sudden flood of meteorites that could have saturated the planets with craters all at once.

Whichever explanation is correct, the early crust of the moon, formed from anorthositic rocks about 4.6 or 4.5 eons ago, was heavily damaged by cratering, so that virtually all traces of the first lava flows are gone. Between 4.5 and 4 eons ago, the crust of the moon must have been pulverized by meteorite impacts, probably shattering and recementing most rocks to a depth of 1-1/4 miles (two km). This explains why astronauts landing in upland sites (Apollo 16 is one example) found not intact blocks of lava, but only *breccias* (rocks formed from shattered fragments of earlier materials).

The further we get from the murky days of 4.6 eons ago, the clearer the story becomes. In fact, some kinds of information are obtained by direct observation. The moon can be observed today to be changing its orbit slowly, spiraling away from Earth — meaning that the moon was closer to Earth in the past. Experts in celestial mechanics, after analyzing these changes, have shown that they result from the influence of tides. Gravitational attraction between Earth and the moon raises tidal bulges on both. Each bulge acts as an independent amount of mass, as it were, and the net effect, under existing conditions in the Earth-moon system, is to slow down Earth's rotation and push the moon outward. It is difficult to calculate exactly when the moon was closest to Earth, but most investigators believe it must have formed near Earth 4.6 eons ago, at which time our planet was turning so fast that a day may have been only about four to eight hours long. The same studies show that the moon would have receded very rapidly, so that it reached nearly its present distance within the first billion years. It is interesting to imagine a lunar landscape of the first few hundred million years, with an Earth looming much larger in the lunar sky than it does now.

What about the final events of the moon's early days, before it became the still place it is today? Around 3.9 eons ago, the moon had craters of all sizes, including a few vast basinlike features hundreds of kilometers in diameter. These basins, sites of the most violent impacts, were underlain by shattered rock and fractures penetrating many tens of kilometers into the moon.

At some depth inside the moon, at this time, there were pockets of partially melted lava. Lunar researches still do not know whether these were created by a new surge of interior heating (for example, heat from slowly decaying radioactive isotopes) or whether they were simply the last remnants of the molten material from earlier heating. In any case, lava from these regions penetrated into the fractures underlying craters and basins and worked its way to the surface, ascending under pressure from the overlying rock.

Vast quantities of lunar lava poured out onto the floors of most large basins, such as Imbrium and Crisium. Probably the floors of these basins sagged, to make up for the space vacated by the lava under the surface. One after another, the lava flows accumulated in the sinking basins, finally forming dark lava plains several kilometers thick.

By about three eons ago, most of this activity had ceased. The outer layers of the moon had virtually run out of liquid lava. The lava plains and the cratered upland hills sat still and silent, disturbed only by occasional silent explosions — impacts from the now-depleted supply of interplanetary debris. Some of the impacts were big by terrestrial standards; those that produced the craters Copernicus and Tycho jetted streamers of bright dust hundreds of kilometers across the moon. But these were small and infrequent events compared to the cratering that occurred in the early days.

From three eons ago to the present, the moon has been relatively quiet and deserted. Perhaps the most important events were those of 1969, 1970 and 1972, when beings from the moon's blue companion walked on its surface for the first time. Now the moon is quiet again, awaiting its next visitors.

Dr. William K. Hartmann is a senior scientist at the Planetary Science Institute in Tucson, Ariz. His research interests are planetary origins and evolution, cratering, and the solar system environment. He is author of the introductory text, **Moons and Planets** *(Wadsworth Publishing Co., 1972), and co-author of* **The New Mars**, *an illustrated NASA account of the Mariner 9 mission.*

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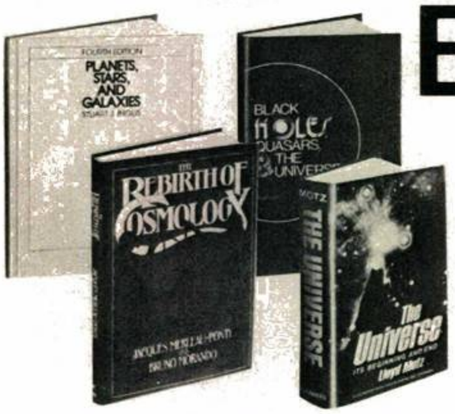

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MAN LOOKS AT MARS

by

William K. Hartmann

July 20, 1976 dawned cold and still in the deserted western wastes of Chryse. At dawn the temperature was about -120 degrees Fahrenheit, but by noon the morning haze burned off and the air warmed to -20 degrees Fahrenheit. Wind was slight and the orange soil and brown rocks were still.

The first sign of anything unusual would have come in the afternoon at about 4:11 local time, when a tiny white starlike object appeared in the darkest part of the Martian sky, high, near the zenith — — the 53-foot-diameter (16m) white parachute of the Viking lander. A keen eye might have spotted a speck falling away from this drifting white star — the 12-foot (3.6m) aluminum aeroshell that had protected the lander during entry into Mars' atmosphere moments before.

The contraption would have been clearly visible, its parachute looking as big as Earth's moon, when at an altitude of 4,000 feet (1,200m) the lander's three engines fired with a scarcely noticeable flame. Within seconds, the parachute cut loose and drifted away. The spacecraft slowed and dropped for another 40 seconds or so. As it dropped the last few feet, some orange dust stirred beneath it. The first lander leg to hit the ground automatically switched off the engines and the ungainly spacecraft bumped to rest. Viking 1 was on Mars.

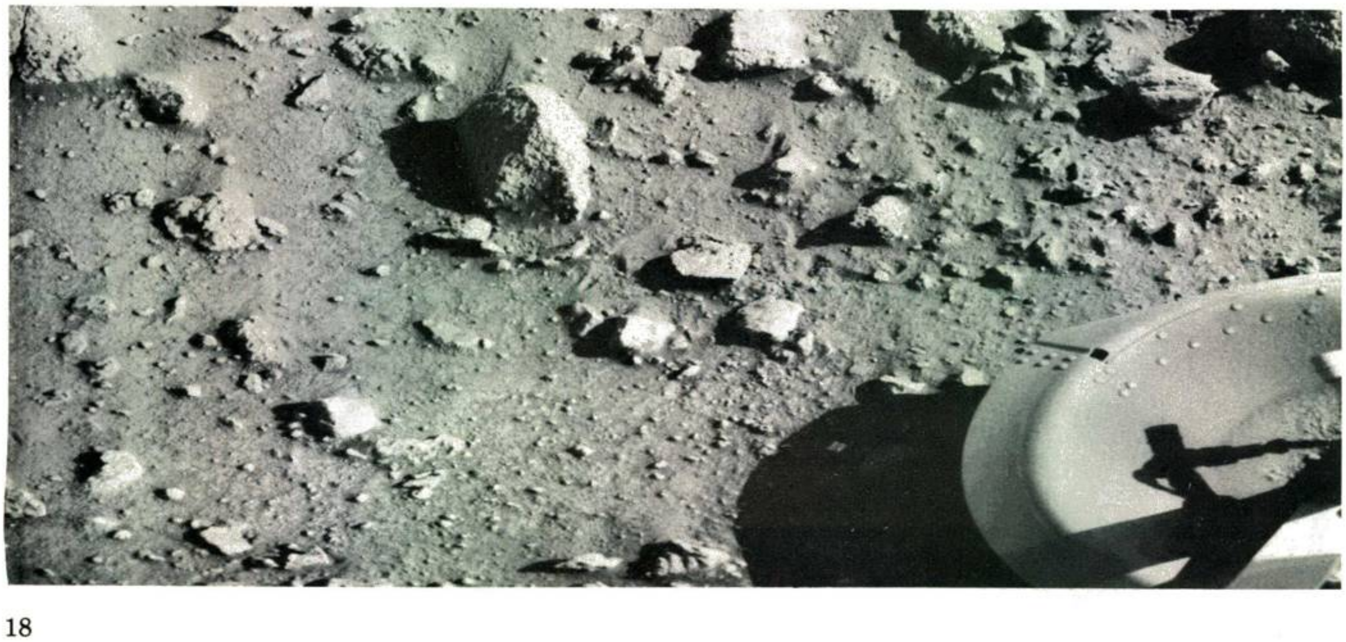
Thus the third extraterrestrial body was open to exploration by humanity, following manned landings on the moon and photography from landers on the surface of Venus. Within minutes of touchdown, the lander cameras began to take and relay pictures of the surface of Mars. It took 18 minutes for the radio signals, traveling at the speed of light, to get back to Earth.

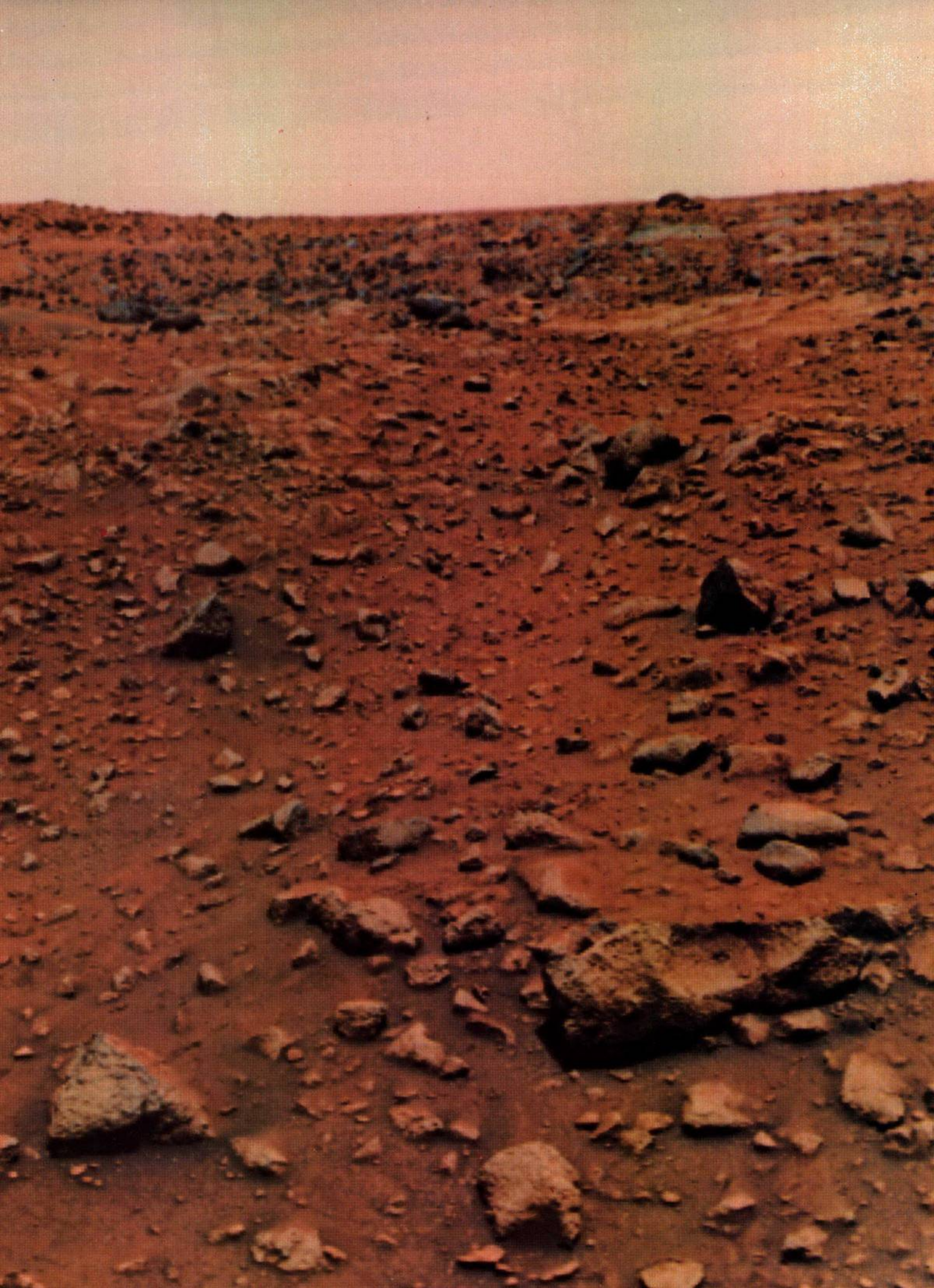
In Pasadena, Calif., hundreds of reporters, scientists, technical staff, NASA administrators, science fiction writers and other guests gathered around television monitors at the Jet Propulsion Laboratory to watch the pictures build up on the screen, segment by segment. Many (though unfortunately not all) television stations around the world carried the same pictures, so that millions shared the first views of the Martian surface.

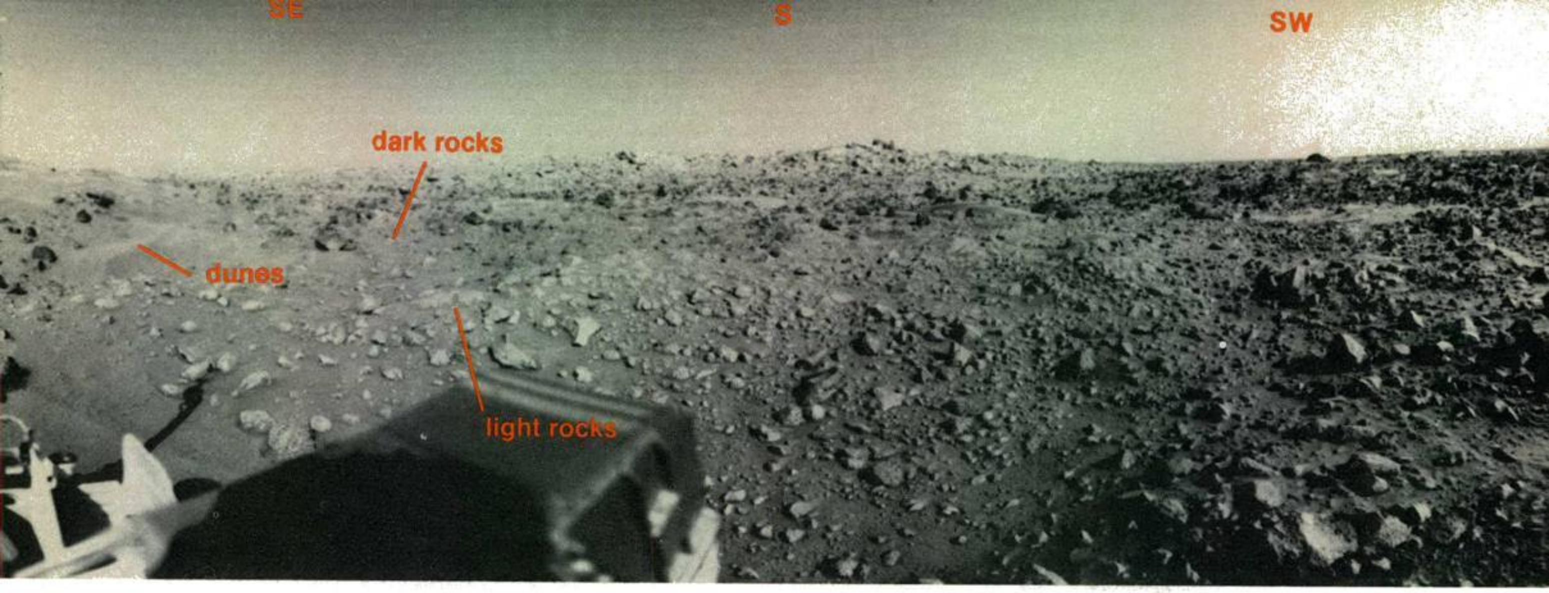
The amount of information derived from Viking's instruments was enormous: the first surface details, the first local climatic measurements, and discovery of nitrogen gas in Mars' atmosphere.

The pictures showed desert terrain stark, but

Below: The first photograph taken on Mars shows flat rocks with angular facets and a finely granulated surface material. Right: The first Viking color photograph shows the surface to be brick red in color. The sky color is incorrect. NASA photographs.







Above: A panoramic view of the surface of Mars taken shortly after landing shows about 300 degrees — almost a wrap-around picture. Opposite: Two views of Mars are shown — one a sunrise picture with the Viking flag in the foreground, and the other a view to the south. NASA photographs.

surprisingly beautiful. Color images transmitted the second day of Viking's operation revealed Mars has a softly rolling landscape with vivid ochre soil, scattered rocks of different brown and tan hues, and a surprisingly bright sky. (Missing were the Martians, the deserted cities, and the strange plants postulated by science fiction romantics who first dreamed the dreams that motivated Martian exploration.) Nonetheless, the scene was scientifically attractive since it revealed a great variety of microenvironments — sand piles, rock surfaces and subsurfaces, and other niches — that implied not only a varied geology, but the possibility of local life-bearing environments. Mars, at least where Viking landed, looked like what most planetary scientists had come to expect after many years of data analysis: a red desert. But the interpretation of the clues in the photographs makes them much more than picture postcards from space.

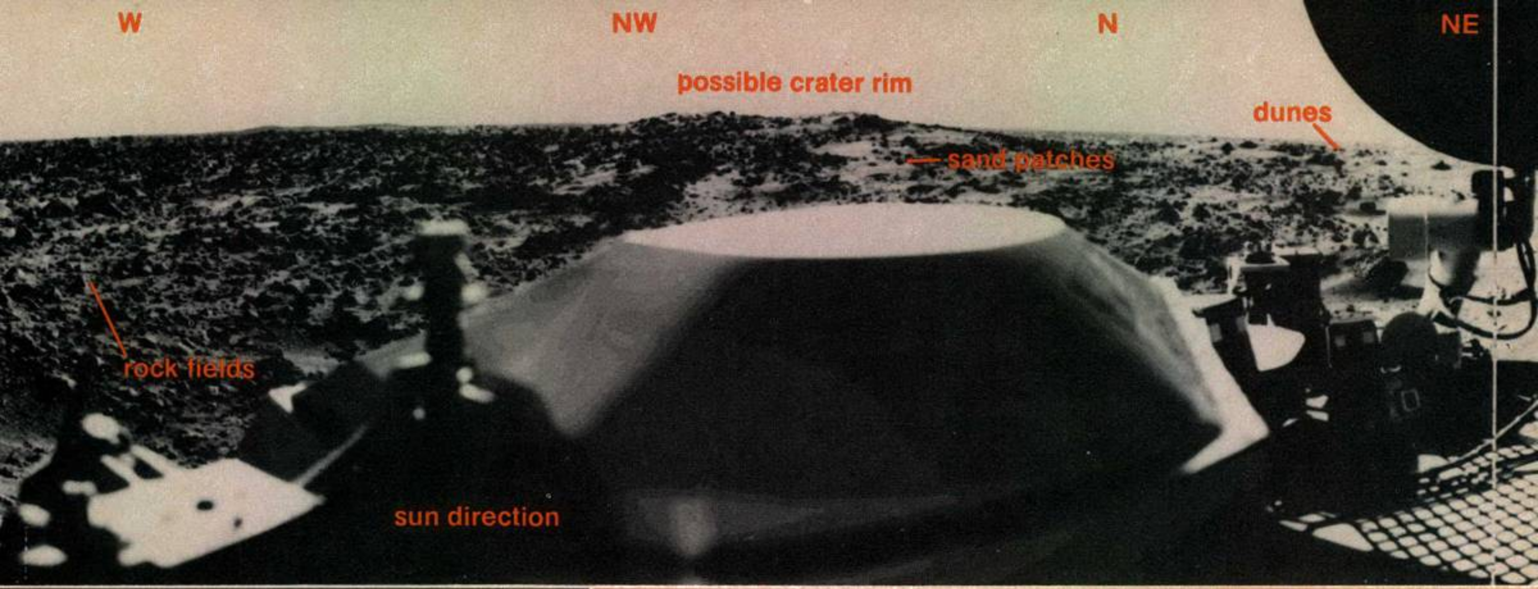
The soil, redder than the larger rocks, supports earlier explanations of why Mars is red. Large rocks have their surfaces continuously weathered away, exposing the dark color of fresh rock. But the small grains, made of individual mineral crystals, are stronger and resistant to erosion. Thus, the surfaces of the small grains are exposed for a long time to environmental agents, causing ferrous iron minerals to weather and oxidize into red colored, rustlike ferric minerals, similar to those in reddish terrestrial deserts. On Earth, small amounts of water in arid environments cause this process, and laboratory studies show that ultraviolet light can cause a similar process. The fact that such reddened coatings have not built up on the larger rocks means that they may erode faster than the oxidation process can occur, perhaps due to the seasonal sand storms that blast rock surfaces. Thus, simple distribution of color and tonality tells a story about long-term geological weathering that has produced the red deserts of Mars (and to a lesser extent, Earth).

Other clues are in the pictures. Size distributions help suggest rock origins; shapes of rocks help discriminate whether fracturing or slow erosion is occurring; flat facets on rocks may be indicative of wind erosion since such facets are found in arid, wind swept deserts on Earth.

The first picture taken was of a region of gravel near a Viking footpad. The scene was chosen to give at least a minimal search for lichens or moss or other plant forms, and to look at possible soil sampler conditions, in case the camera later failed. At the left side of the first picture, diagonal striations in the powder at lower left are similar to typical patterns formed by prevailing winds blowing across dusty surfaces (probably from lower left to upper right). Although some striations could be due to exhaust gases from the descent engines, these particular striations seem to match wind directions revealed in more distant patterns in the second picture.

The largest rocks in the first picture (such as the one in the upper left) are estimated by scientists to be about four to six inches across, based on the camera geometry. The rock mentioned reveals both pits and cracks. The fracture, as well as the flat angular surfaces, may indicate that the rocks have been violently broken from parent strata, perhaps by ancient impacts. One interpretation of the pits is that they are *vesicles*, or bubblelike holes that appear in gas-charged lava as it extrudes on a planetary surface — but it is too early to confirm that the rocks are lava fragments.

More rocks and striated dust appear in the middle of the first picture. The pattern of partial burial of rocks suggests to many scientists that this surface has been built up something like the lunar regolith or soil layer, but with the addition of wind. Orbiter photos show that the Chryse plains may be lava plains, fundamentally similar to the lunar maria. (The theoretical interpretation would be that craters have pocked them, churning up debris and producing a mixture and fractured rocks, similar to the regoliths observed by lunar astronauts.) Water may have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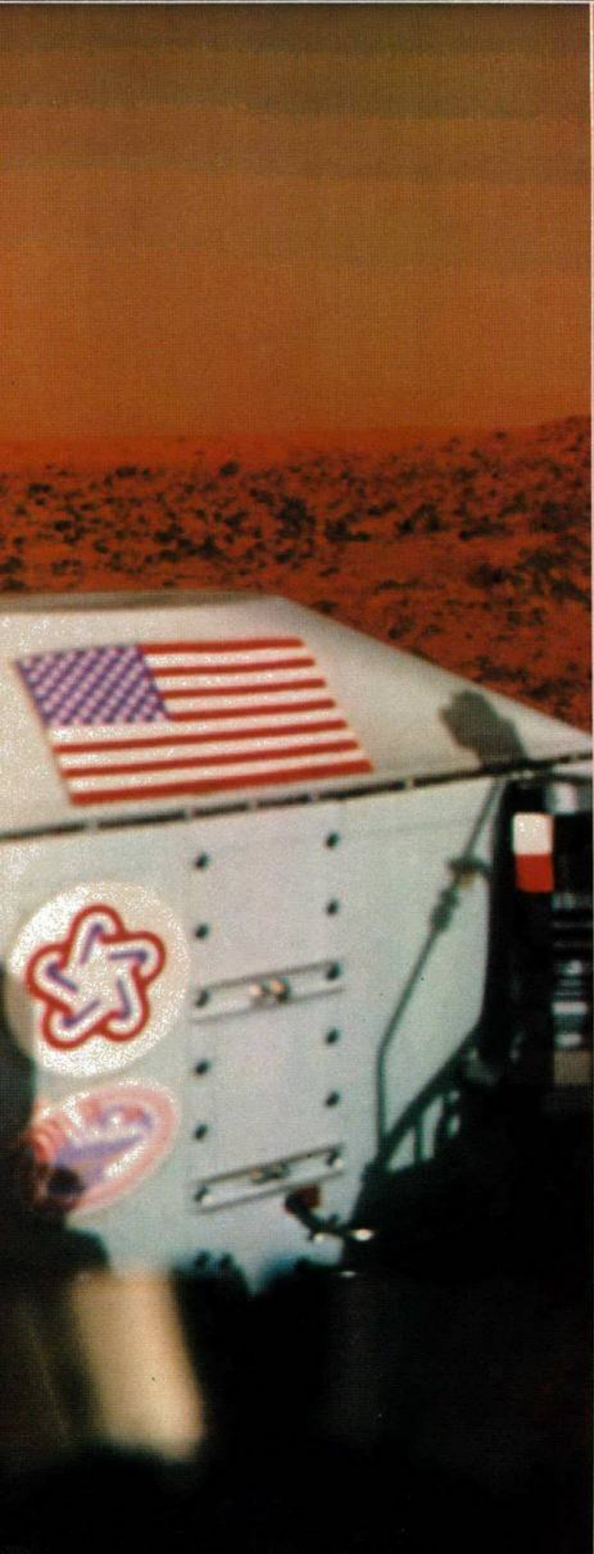

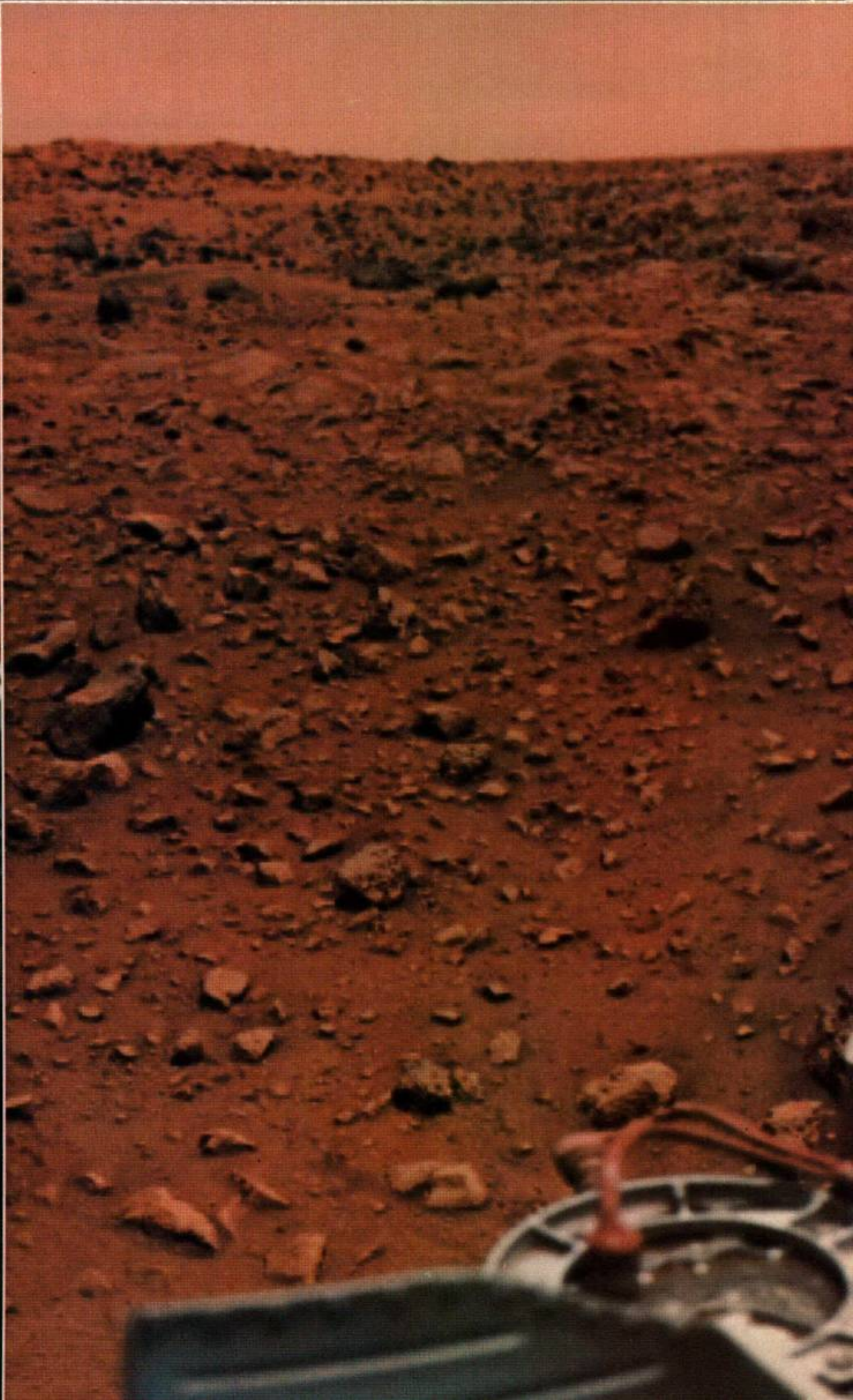

flowed over them in the past, creating large and small gullies. More recently, wind and dust storms have played their roles. Fine dust has been blown away in some areas, while dunes have accumulated in other areas and gullies may have been filled in. As fine dust is blown away, the heavier rocks are left behind. If the process goes far enough, rocks and rock chips may form a protective "armor" over the dust — called *desert pavements.* It is often found in the American southwest and other desert regions. The immediate surroundings of the Viking lander, then, could be called a partially-formed desert pavement.

The surface is quite firm. Lander footpad No. 3 penetrated only about 1.4 inches (3.5cm) in spite of hitting about as hard as you would hit if you jumped off a one foot (30cm) ledge on Earth. However, a handful of dislodged dust settled in the concave upper surface of the footpad, as the picture shows. (The flattened far edge of the footpad is not a rock-caused dent, but a design feature of the pad itself.)

A second picture from Mars was transmitted a few minutes after the landing. The camera scanned a panorama of the horizon covering roughly 300 degrees from east through south to west.

Starting in the east, a varied landscape is seen. Dark rocks stand out on a field of rolling sand dunes. A gentle gully reveals the far horizon where unusual light hills can be seen — an interesting candidate for later high-resolution photography. In this direction, the nearer rocks are distinctly lighter than the distant dark rocks, proving that different rock types are present on Mars. Could these indicate a distinct differentiation into different types of crustal material, such as the dark basaltic and light granitic rocks of Earth? Further data will be needed to answer such a basic question.

Moving to the right, or south, the scene becomes rougher and more rock-strewn. Several large rocks, probably several meters (about 6 to 10 feet) across, protrude on the rolling horizon. (One has been nicknamed "Volkswagen".) The rock swarm is especially dense toward the south, where the horizon has almost exactly the profile of Arizona's meteor crater (or some volcanic calderas) when seen from a distance. This raises the possibility that the rocks are not uniformly mixed with the soil, but are a local surfacial cluster blasted out of a moderate sized crater somewhere to the south.

Proceeding toward the west (right), patches of sand or dust appear, and the rocks give way to a dune field in the northwest, partly obscured by the disk shaped antenna. Especially interesting, between the spacecraft instruments in the far right, is a large rock with sand or dust piled up against its left side. This is a classic pattern caused by prevailing winds which scoop out dust from the windward side and pile it on the leeward side, in the *wind shadow.* Orientation of the features suggests that the last prevailing wind in this immediate region has come from behind the spacecraft in this view — that is, from the north and blowing toward the south, which seems to conflict with directions of wind streaks detected from orbital photography.

The Martian sky surprised scientists: It was much brighter than expected. Most prelanding artists pictured the sky much darker than the landscape, but the first photographs showed that the sky is brighter, as it is on Earth. (Since the picture is composed of discrete shades of gray, the darker parts of the sky, at the left, show a layered effect created by photo contours of equal intensity.) Toward the right, or southwest, these give way to an "overexposed" sky where the afternoon sun hangs above the horizon. Measurements indicated that the Martian sky is about 100 times brighter in this picture than it would be if the light were scattered purely by atmospheric gas. Viking scientist Dr. James Pollack said that the light comes from reflection or scattering by dust particles suspended in the air. This is consistent with years of Earth based and orbital measurements of dust clouds and dust storms in Mars' atmosphere. A second surprise came from Pollack's analysis of pictures taken with different colored filters: a pinkish or orangy hue dominates the sky. Viking scientists Dr. Alan Binder explained that the first pictures were calibrated by color standards on the spacecraft. The vivid soil colors were quite accurate in all reproductions, but the pale sky color was subject to distorted shadings, just as delicate flesh tones can be easily distorted by the color controls of a home television set. The final color calibration, therefore, is expected to reveal a bright and slightly orange sky, as would be expected if most of the light is scattered off orange airborne dust particles.

The Martian dust count certainly varies from day to day, ranging from nearly clear to dense dust storm conditions. On some days the sky might have the dark, deep blue color associated with the thin gaseous atmosphere, while on other days when dust has been raised, it would be definitely orange. On the day of the first landing, a thin cloud was spotted somewhat to the left of the sun; during other seasons and other times of day, gray or whitish hazes may obscure the sky.

Other interesting data about Mars came from other instruments on the lander. Measurements during the first day indicate a nighttime air temperature of -122 degrees Fahrenheit (-87 degrees Centigrade), and daytime high above -22 degrees Fahrenheit (-30 degrees Centigrade), and light winds ranging up to 15 m.p.h. In the thin air, these winds are insufficient to disturb the local dust.

Thus, the photographs made on Mars provoke fascinating new thoughts about Mars — and Earth. The Martians aren't to be seen yet. The plants and the alien artifacts aren't in evidence. But all conditions for life seem to be there, or at least *were* there in the past.

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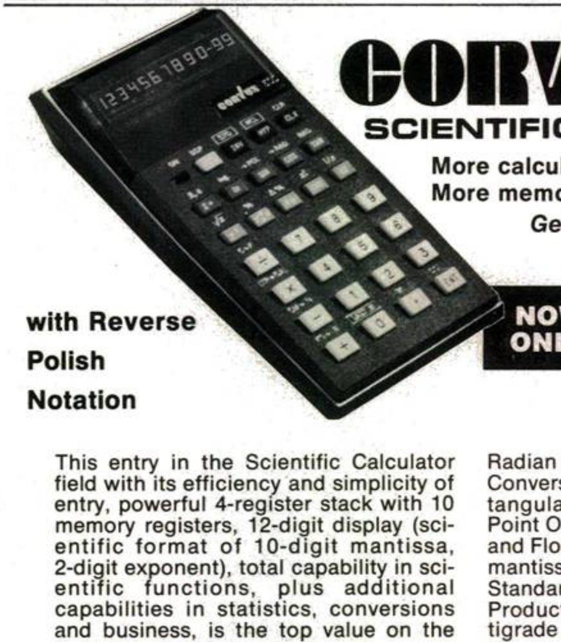

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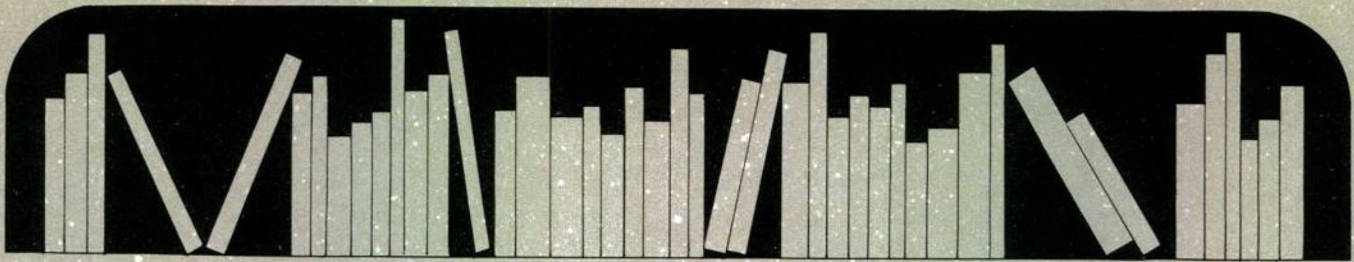


ASTRONOMY REVIEWS

History of Rocketry and Space Travel

by WERNHER von BRAUN and
FREDERICK I. ORDWAY III

308 pages, hardcover, $25.00
Thomas Y. Crowell Co. (1975)

What once were current events seen on evening news programs are now chapters in dusty history books. People over 30 can remember the first artificial Earth satellites; high school students today were children during the first manned moon flights. Even the exciting Skylab space cliffhanger and record breaker may seem to have been in the newspapers only yesterday — but it was three years ago. The **History of Rocketry and Space Travel** includes all these recent events, and much more.

This monumental chronology spans thousands of years. It begins with early dreams of space voyages and concepts of the universe. Parallel with these ideas, the rocket technology is also described — from the Chinese "fire arrows" to the British artillery which left "the rockets' red glare" over Fort McHenry. Then, late in the 19th century, these two independent developments came together and the way into space began to open.

Three space prophets — the German Oberth, the American Goddard, and the Polish Ziolkowski (spelled Tsiolkovsky in Russian) — laid the foundations of 20th century astronautics. The book follows their ideas from concept to design to reality. Only a few weeks after the 100th anniversary of Ziolkowski's birth, the Russians launched "Sputnik", the world's first artificial Earth satellite.

This is a wide-ranging, ambitious historical work, written by one of the men who made space history himself and by another prolific space popularizer and serious space history researcher. The result of their collaboration is one of the best space history books ever compiled. It is a terrific summary of the dozens of winding paths which led to Neil Armstrong's small step onto the moon. It is less useful as a roadmap of the future — but then that was never its intention.

Interspersed with chapters on rocketry and space travel are color portfolios which have some distant thematic connection with the text, but are visually stunning. Black and white illustrations must number in the hundreds.

All the major space stories of the 1950s, the 1960s, and the first half of the 1970s are covered, along with some minor ones which make fascinating footnotes but might have been worthy of more attention. One such example is the once classified Navy project in 1958 which tried without success to launch small Earth satellites on rockets fired from carrier based jet fighters. Observers close to the national space program were familiar with the bare outlines of this project but would have liked to have seen more details. This clearly must await another history book.

The first edition of this book was written in the mid-1960s, when the moon landing was still on the drawing boards. Following the first successful landings, the book was updated and reissued. Now that Apollo and Skylab are over and there will be a pause of several years before the Space Shuttle blasts off, a third edition has been issued. The publisher must be congratulated for updating and reissuing a space book in a year when space books do not seem to be catching the public's fancy.

Unfortunately, the scotch tape is quite evident in the book where poorly fitting and badly transitioned new sections have been clamped onto the earlier editions. The older sections have not been updated to tie in with later additions. Nor are the new sections as carefully proofed for precise correctness as is called for in such a technologically oriented book. One Apollo flight took 11 days to return to Earth, according to the latest chapter (it really takes only three) on later moon landings. The Viking Mars probe parachutes are omitted. The authors do not seem to understand what "solar occultation" means for an interplanetary space probe. But these are trivialities.

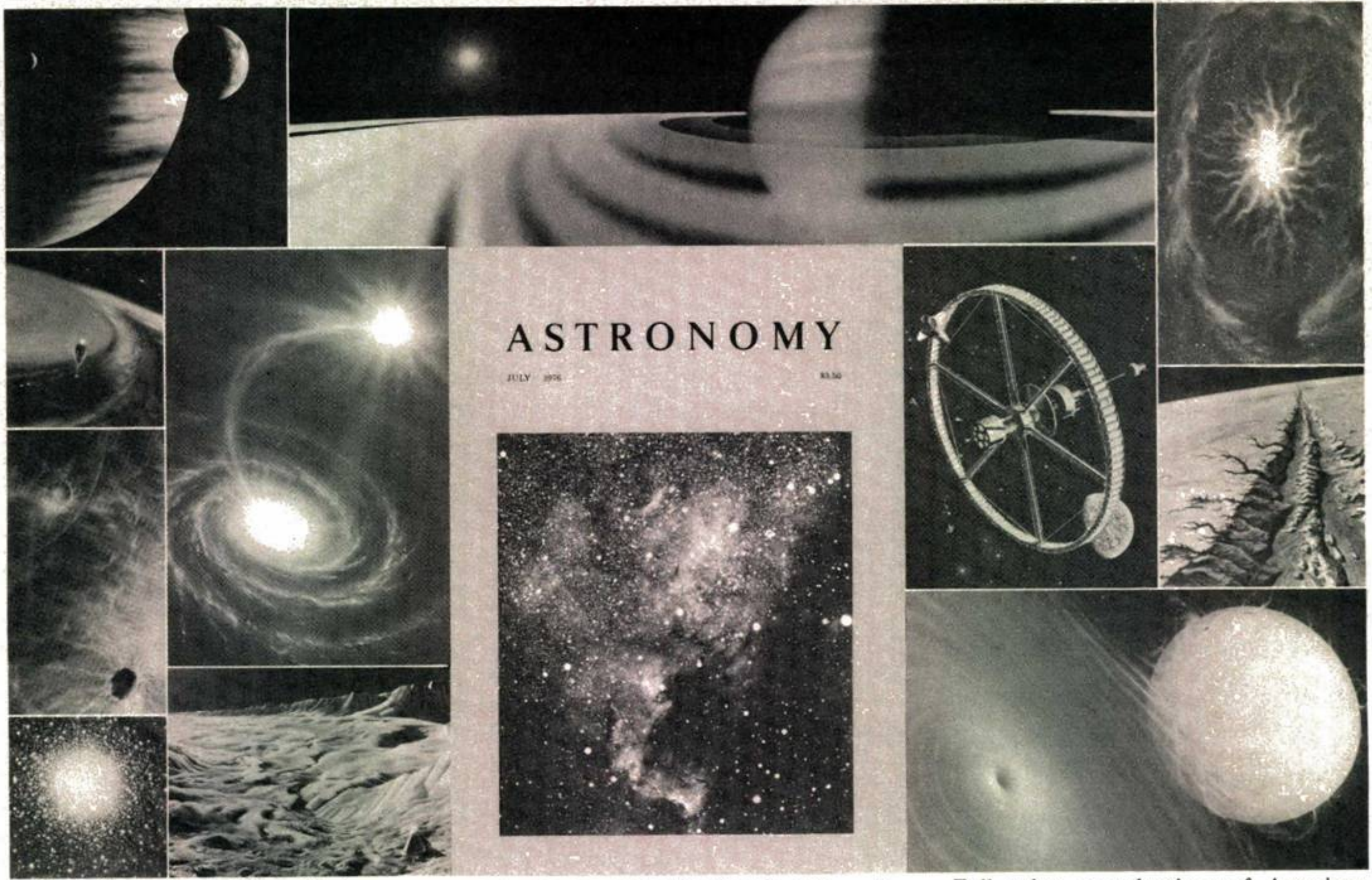
The section on Soviet "cosmonautics" is about the best coverage of this mysterious and enigmatic topic to be found in a general survey work. Its one major weakness, however, must be pointed out. It seems to be the result of the basic structure of the book and the superficiality with which the new editions were put together.

Far too little mention is made of Sergey Korolev, the "father of the Soviet space program", who almost singlehandedly directed the Sputnik, Lunik, Vostok, Cosmos and Voskhod programs; without his brilliant achievements, the United States would never have been motivated into its Apollo moon program. His sudden death in 1966 (at the age of 59) was a crushing blow to the Soviets and probably cost them the moon race. However, his identity had been kept secret and his importance was not realized in the West when the first edition of this book was written.

By the time his place in space history was fully appreciated (the USSR honored him posthumously), it would have taken a major rewrite of many parts of the book to give him all the credit he deserved. This could have been done in the second edition, or even in this edition. It is one of the major shortcomings of this history that the authors did not consider the rewriting worth the effort. Korolev (and fidelity to the true history of space exploration) deserved better.

Hopefully this oversight can be corrected for the next edition of the book, perhaps in five or six years when Space Shuttle and Spacelab and Viking become fact instead of forecast. If this history becomes the classic it certainly deserves to be, new sections will have to be added and old sections rewritten with the revelations of hindsight and perspective afforded by the passage of time. Such is the essence of historical research, and this book is excellent history. *James E. Oberg.*

Man's Dream of Worlds Unseen



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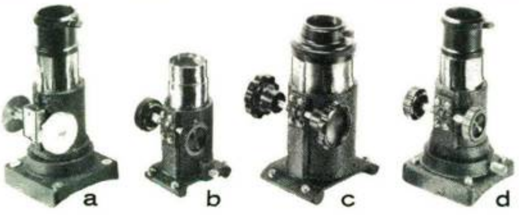

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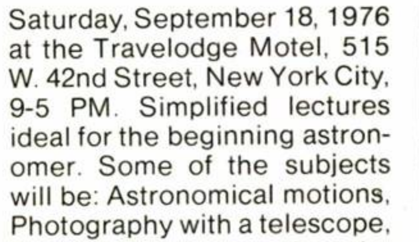

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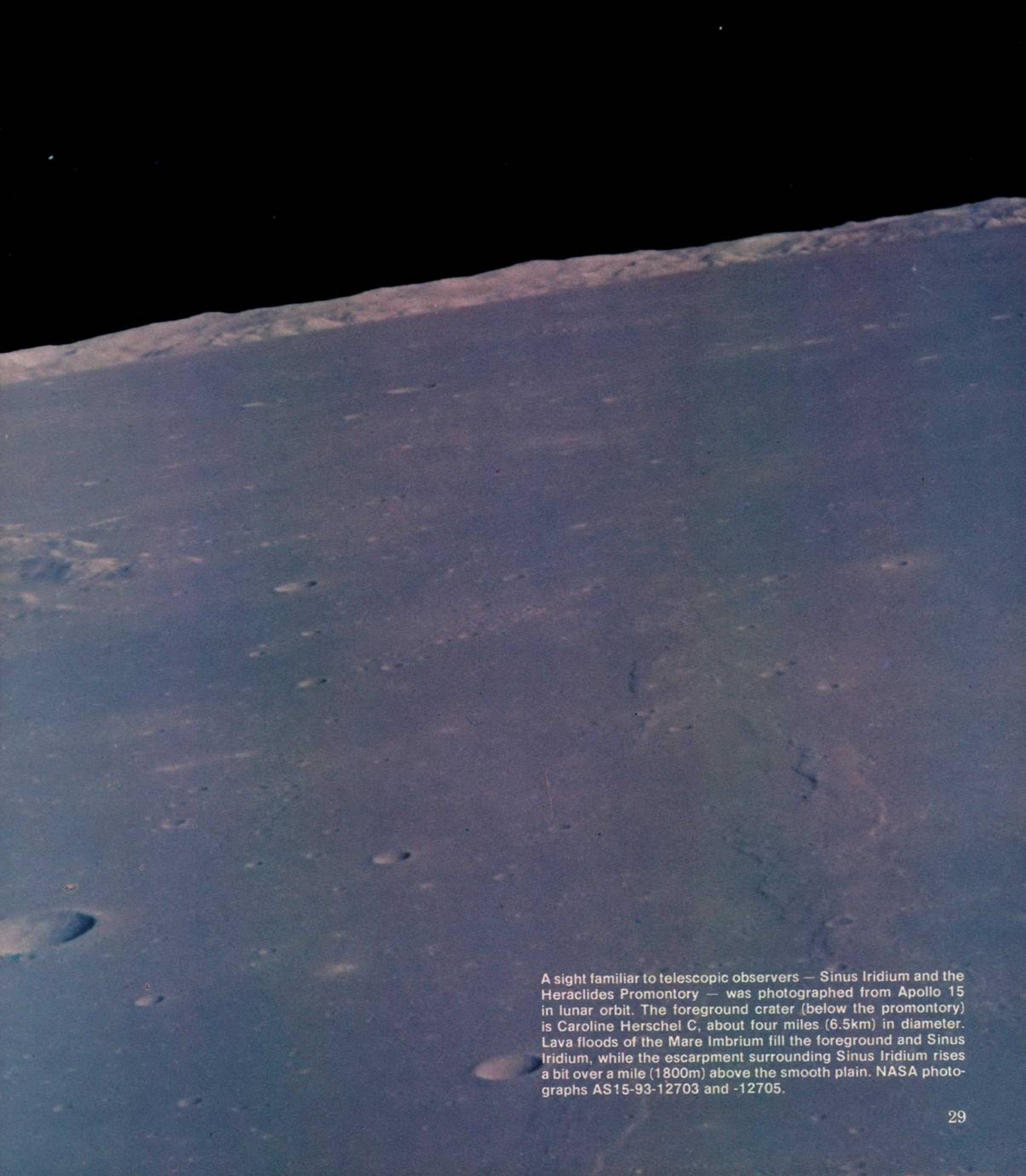
SCIENCE ON THE MOON

by Eric Burgess and James E. Oberg

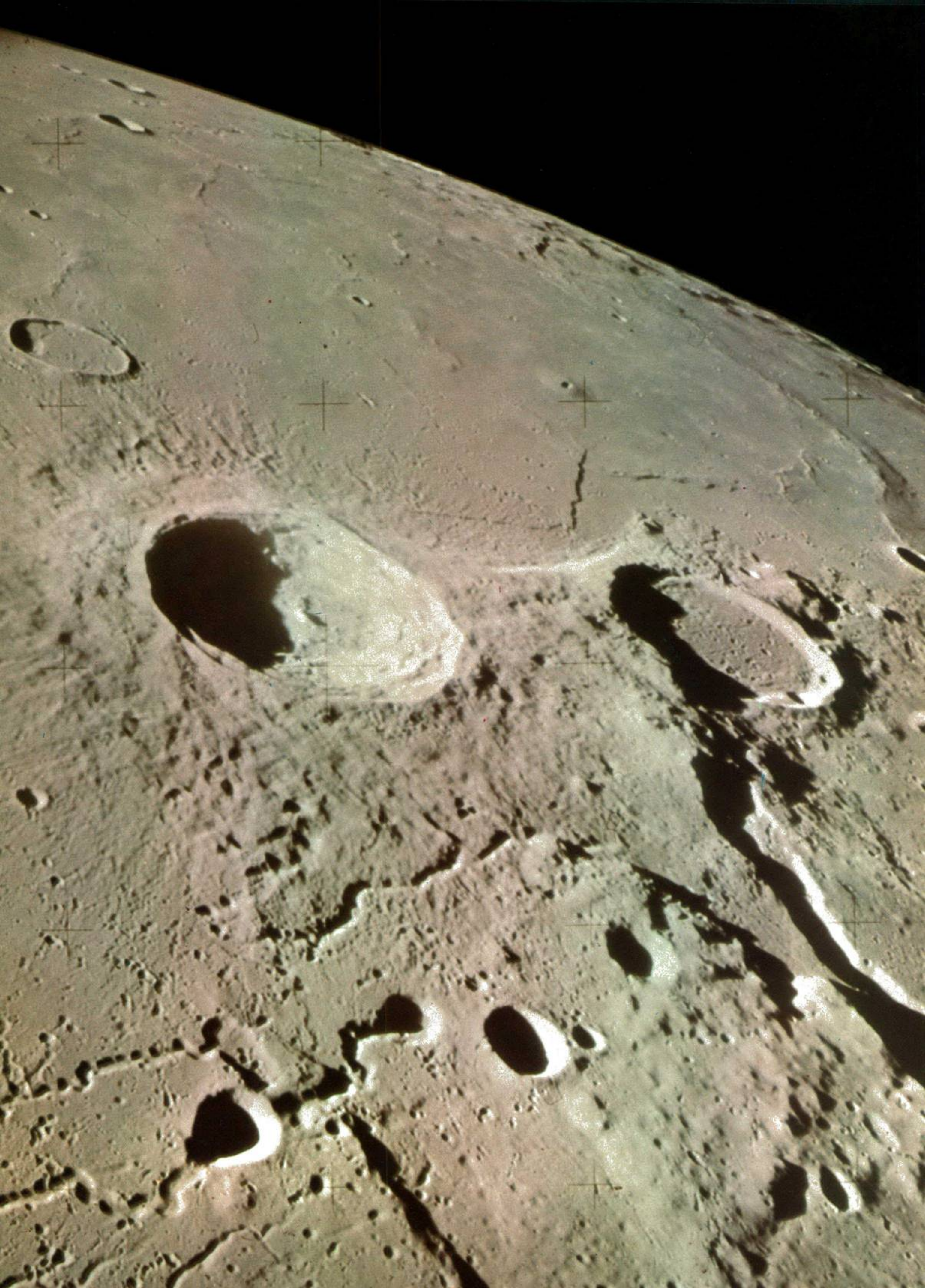
Lunar data — the type of data which the scientists don't usually discuss too much in public — sound like a rockhound's delight or a geologist's paradise. Rocks are all there are on the moon — rocks that have been battered and bashed, fractured, heated, melted, and flung around. Their histories — which can be deduced from their chemistry, structure, and physical makeup — are all man has to go on in answering the big questions about the early history of the solar system and the moon. Each bit of information gained may rule out some theories, require explanations from others, or suggest new hypotheses that had not been proposed before. As more infor-

mation becomes available, the theories currently acceptable in view of available evidence may become a more and more accurate description of what really did happen billions of years ago.

Since the first successful flyby of the moon by the Russian spacecraft Lunik 1 in January 1959, 21 unmanned Soviet spacecraft and 13 unmanned and 8 manned American spacecraft have amassed a wealth of scientific information about the moon. Much of our new information, as well as about 850 pounds of lunar materials (rocks) returned to Earth will continue to be analyzed for decades to come. Many of the questions that astronomers asked about the moon before the space age began have already been answered and many of the older speculative theories have succumbed in light of new findings.



A sight familiar to telescopic observers — Sinus Iridium and the Heraclides Promontory — was photographed from Apollo 15 in lunar orbit. The foreground crater (below the promontory) is Caroline Herschel C, about four miles (6.5km) in diameter. Lava floods of the Mare Imbrium fill the foreground and Sinus Iridium, while the escarpment surrounding Sinus Iridium rises a bit over a mile (1800m) above the smooth plain. NASA photographs AS15-93-12703 and -12705.



Just what *are* the new findings? What have we learned from the lunar rocks?

Rocks

The material of the moon contains essentially the same chemical elements believed to be present in the rest of the solar system. However, the basic composition of the moon differs somewhat from Earth as well as the "primitive" chondritic meteorites.

The oldest materials sampled from the moon are rocks about 4.6 eons old, dating from close to the time at which the moon is believed to have accreted from the solar nebula. This age is consistent with evidence that Earth and the meteorites originated about 4.6 eons ago.

The crustal rocks of the moon are mainly igneous basalts on the mare surfaces, and metamorphosed or brecciated (literally, broken) rocks on the highlands. Breccias are the lunar analogs of sedimentary terrestrial rocks. They are produced by the weathering process of meteor impacts. Mare basaltic lavas — similar to terrestrial lavas, except that they are richer in titanium — contain no water. In fact, the moon appears never to have possessed water in any quantity (although some speculation today suggests there might be water frozen in the polar regions).

The moon has never had free oxygen, and it's also deficient in carbon (both are basics for the type of life we know). No evidence of life was found in any of the samples brought back, nor were there any fossil life forms found in the rocks. No recognizable artifacts on the moon (other than those we have placed there) can be attributed to the action of living systems, intelligent or otherwise. Though two Apollo missions reported seeing bright flashes on the moon, these are attributed to impacts of small meteors. While on Earth, life appears to have flourished for several billion years, lunar rocks show a moon desolate and barren of life.

Lunar Minerology

Probably because lunar material could not react with an atmosphere or water, the moon has comparatively few mineral species — 100 compared with Earth's 2,000. The four principal lunar minerals are *pyroxene* (a calcium-iron-magnesium silicate), *plagioclase feldspar* (a calcium-aluminum silicate), *olivine* (an iron-magnesium silicate), and *ilmenite* (an iron-titanium oxide).

Lunar pyroxenes, even in single crystals, show greater variations than terrestrial pyroxenes. Plagioclase on the moon is richer in calcium, with some samples consisting of almost pure feldspar. This mineral seems to be concentrated in the lunar highlands, probably the end product of igneous processes. Olivines crystallize early from hot magma, and in the basalts on the moon they are rich in magnesium; some are also rich in iron. Lunar ilmenite is nearly pure iron-titanium oxide.

Three major lunar rock types have been identified in the samples returned from the moon:

1) Anorthosites are abundant, very ancient rocks, but are not primordial. These rocks may be 30 miles (50km) thick, and probably formed from an ocean of rock encompassing the moon early in its history.

2) KREEP norite, most common in highland areas, is also found elsewhere. Another ancient rock type (but again not a primordial rock), it probably formed deep in the lunar crust by partial melting due to radioactive heating.

3) Basalt, youngest of the lunar rocks, is the common rock of lava flows of the lunar maria and flooded craters. Most probably it was produced by partial melting within the moon's upper mantle as a result of radioactive processes. It reached the surface through faults produced by major impacts.

Lunar Highlands

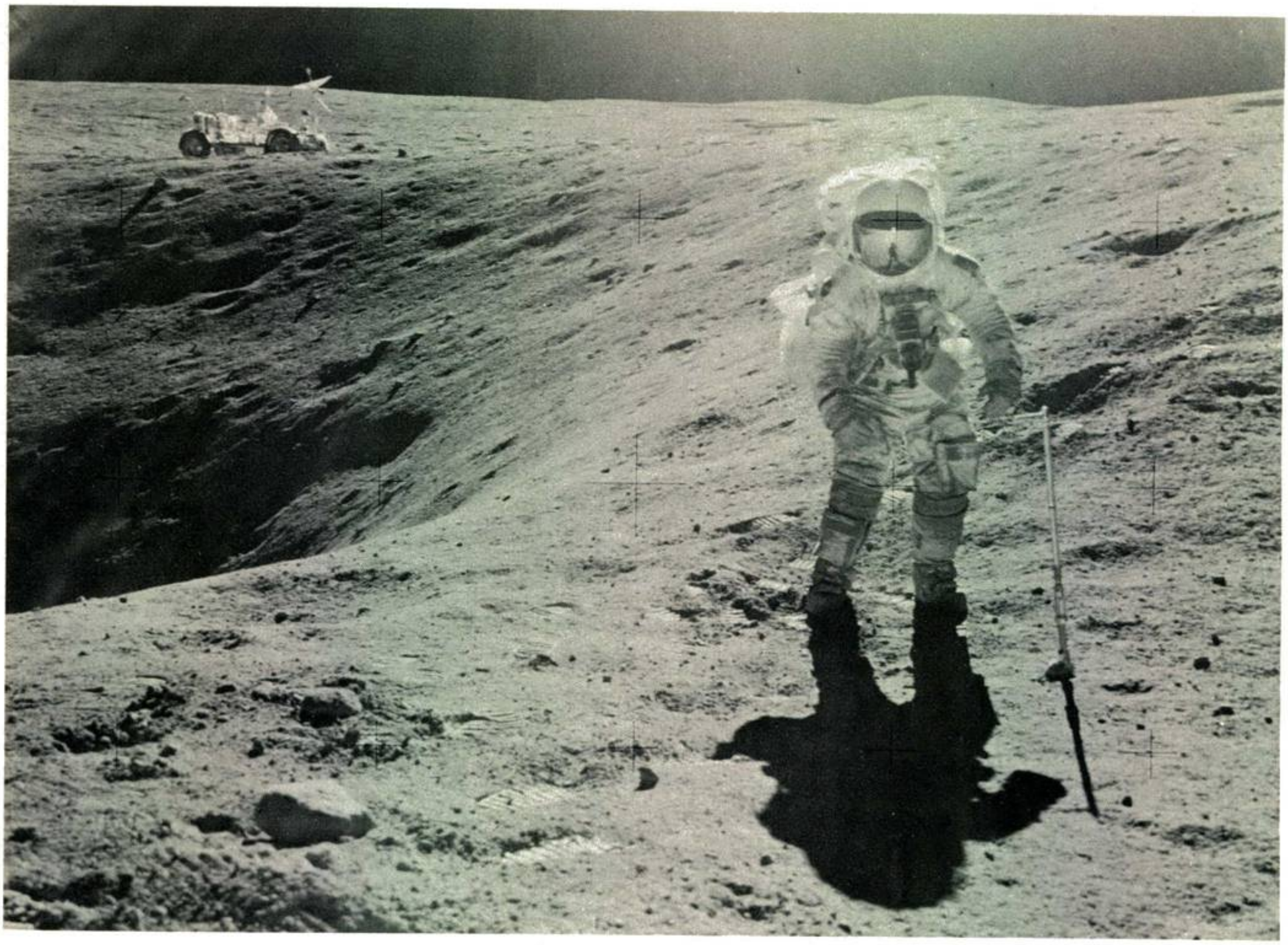
The lunar highlands are the oldest lunar surfaces, possibly an ancient crust. Pounded by bodies from space which blasted out craters on top of craters, the highland rocks have been repeatedly broken by impacts forming breccias. The volcanic plutonic rocks in these breccias include norites, dunites, and spinal troctolites — types of rocks which probably crystallized several miles deep within the original lunar crust.

Some small fragments of other volcanic highland rocks are richer in potassium, rare Earth elements, and phosphorous (named *KREEP* for their chemical symbols). KREEP basalts are believed to have been thrown all over the surface of the moon by meteorites impacting the highlands. Whether KREEP originated from volcanic activity in the highlands or from local melts produced by the impacts is not known.

The igneous processes that formed the original lunar crust are still problematic because the rocks have been so violently and repeatedly pounded by the crater-forming impacts. Crustal material has been spread over wide areas — in fact, even today any rock on the surface of the moon is struck and shattered by a meteorite within 100 million years. Metamorphosed lunar rocks have been cycled through the brecciating process many times during the billions of years since the crust formed; some big boulders are found to be breccias within breccias.

All ancient rocks have been changed. Some analyses suggest that the lunar highlands formed 3.9 to 4.0 eons ago, but they may be older because of an averaging effect in the age-dating methods used. A more recently developed age-dating techni-

Aristarchus — a relatively new and brilliantly reflective crater — and its hummocky ejecta blanket dominate the left side of this Apollo 15 orbital view. The Cobra's Head and the Schröter Valley are features of volcanic nature, possibly associated with the formation of Aristarchus. This area is associated with the reddish "lunar transient phenomena" glows that have been telescopically observed. NASA photograph AS15-88-11980.



que places a major melting and separation of lunar rocks at 4.4 eons ago, perhaps the time at which the crust solidified.

Craters

Lunar science has finally settled all speculation about lunar craters being volcanic: Almost all craters are the result of impacts. From a large event that formed basins 600 miles across, to microscopic pits only 1/100,000 inch across, the impact process has spread lunar materials across vast areas of surface, forming layers of ejecta and fields of secondary craters.

There may have been two distinct periods of cratering: the "tail end" of accretion followed by a lull, and then a rain of bodies from a later cataclysmic event. Cratering continues to the present day, but at a very low rate. Craters stay fresh-looking on the moon for hundreds of millions of years; the youngest have bright ray systems or halos which in some places are interrupted by lava flows that must have occurred after the crater ray systems were formed. There are several very young craters on the moon, such as Copernicus and Tycho; the former dates from about 600 million years ago, the latter from about 200 million years ago. The creation of either crater would have been a spectacular sight if man had been around on Earth to witness it.

Mare Basins

Mare basins are the largest lunar craters; they are prominent on the nearside because they are filled with dark basalt. Mare basins are present on the farside but because they are not flooded there, they are not as readily recognized. We now have a clear picture of mare formation: When an asteroid size body hits the moon, it excavates rock from deep in the crust and produces a huge crater. The surrounding surface ripples in spreading waves, and some of the fragments blast secondary craters. Most of the debris falls back near the primary impact site, or spreads as a curtain of material which has gouged the surface, burying secondary craters and smoothing out hills and valleys. The walls of the initial large crater collapse inward, and its center rebounds — uplifting into a mountainous area. Rocks, melted by the impact energy, flow to form lava pools. Inward slippage of walls produces concentric mountain rings and high escarpments facing the basin. Pools of melted rock collect in the valleys. Layering from earlier periods of bombardment are revealed on the cliff faces of upturned blocks of rock. Finally, hundreds of millions of years later, many of the impact basins are flooded by lava to form the dark mare surfaces.

At the Darcartes site, an Apollo 16 astronaut stands by Plum crater — camera strapped to his chest, sample collector before him — on a mission to investigate the light colored highland material of the Cayley Formation. NASA photograph AS16-114-18423.

The Regolith

Draped over the hard rock of the entire moon are layers of unconsolidated debris — the lunar regolith — generated by the impact of meteorites for billions of years. The lunar regolith differs from terrestrial soil because it has never interacted with water, atmosphere or living things. The thickness of the regolith varies; it is thin or nonexistent over crater rims (where bedrock may be exposed), but in the highlands, it may be at a depth of at least several yards. Core samples from several Apollo landing sites showed that the regolith has layers, and that each layer is well mixed within itself. The layering is local as is evidenced by its different forms from core to core. Layering was seen in the walls of the Hadley Rill and cliffs of the Apennine foothills by Apollo 15. The top layers are turned over very frequently, and deep layers much more slowly. A meter below the surface, the soil can remain undisturbed for hundreds of millions of years. But close to the surface, a few millimeters are turned over hundreds of times in a million years.

At any site the lunar soil contains not only underlying bedrock, but also small quantities of material from great distances and material from infalling meteorites. The soil contains many tiny glass *spherules*. Some of the spherules are teardrop shaped, while others are jagged; some are emerald green, and some are orange. Many are believed to have been formed by the heating produced by meteoric impacts; however, the brightly colored glasses may have originated from lava fountains at the edge of the mare plains. The glass beads contain high proportions of volatiles which, as they escaped from the lavas, probably caused the beads to form by rapidly cooling the lavas. Other glass spherules formed as molten rock splashed from impact sites. In subsequent impacts of meteorites, the glasses stuck in other solid particles in the regolith, producing metamorphosed rocks.

The Lunar Interior

New data from Apollo's seismic network (ALSEP stations) has provided a picture of moonquakes and the outer regions of the moon. Lunar seismic events are different from terrestrial earthquakes; the records show vibrations are long-lived and reverberatory, in a fashion that confirms the dry rigid nature of the lunar rocks. The outermost 1km-thick layer of the moon is composed of loosely packed rubble rather than hard rock. Deeper, the rubble is consolidated, or there may be fractured bedrock. Still deeper, below 15-1/2 miles (25km), seismic waves propagate in a way that suggests anorthositic gabbros. But at a depth of 37-1/2 miles (60km), an abrupt change occurs which seems to indicate the end of the crust and the beginning of a mantle consisting of rocks equivalent to terrestrial pyroxenites. The mantle extends at least as deep as 95 miles (150km).

Moonquakes occur below the mantle at depths of hundreds of kilometers, at about 50 identifiable places. They are governed by a monthly tidal cycle due to the moon's motion about Earth. A longer cycle, governed by solar tides, also occurs. Shallow moonquakes — perhaps related to the relief of crustal stress — that have no particular pattern, occur, but less frequently. There are also many microquakes produced by the extreme daytime solar heating and nighttime cooling of the moon's surface.

The majority of the deep cyclic moonquakes occur at the top of a lunar *asthenosphere*. Below a thick *lithosphere* (crust), the asthenosphere may still be partially molten — its heat slowly escaping through the solid mantle and crust to the lunar surface. Unfortunately, heat flow experiments made by two of the Apollo missions have not been conclusive because they were made at the edges of basaltic lava flows which may not be truly typical of the whole moon. Surprisingly, the heat flows recorded were high — about 1/2 the average heat flow at Earth's surface.

One way of measuring the interior temperature of the moon is by the magnetic fields induced in the materials of the moon by fields associated with the solar wind. There appears to be a rapid increase (about six degrees Centigrade per kilometer) to a depth of 150 miles (250km) and then an almost uniform temperature with increasing depth to the maximum explored by this experiment. It seems that at about 600 miles (1,000km) the lunar interior is no hotter today than 2,732 degrees Fahrenheit (1,500 degrees Centigrade). Below the lithosphere the temperature is unknown, but the moon seems to be relatively cool compared with Earth — despite the possibly misleading measurements of high heat flow.

The induced magnetic field experiments neither confirm nor deny the hypothesis that parts of the asthenosphere may be molten today. What seems clear is that any present-day activity within the moon is confined to the asthenosphere. The rigid shell of the lunar lithosphere prevents any flow of lava to the surface, and any present-day tectonic movement of the crust. Today the moon seems virtually inactive as a planetary body, any activity is "locked in", and its planetary evolution ended billions of years ago.

Continuing Exploration of the Moon

The end of Apollo seemed to leave the exploration of the moon entirely to the Soviet Union. However, the United States moon study program remains quite active, while at the same time the USSR's own robot explorer project is preparing for an exciting new phase of lunar exploration.

At the Apollo landing sites, special instruments and equipment (the ALSEPs, or Apollo Lunar Surface Experiment Packages) continue to relay scientific readings to Earth. Three laser reflectors help measure the Earth-moon distance. Four seismometers listen for moonquakes and meteor impacts. Thermometers plugged into the moon's crust measure the flow of heat between the surface and the interior. Magnetometers and ion detectors monitor the interaction between the solar and lunar atmospheres.

The oldest of these automatic stations, ALSEP 12, will celebrate its seventh birthday on the moon later this year. Left behind by astronauts in 1969, it was designed for a one year lifetime. Four other ALSEPS were set up on later flights. Their unexpectedly long life has resulted in a scientific bonanza for lunar scientists.

With the initial survey and cataloging of the Apollo moon rock samples now complete, scientists are beginning detailed sample-by-sample tests. More than 90 percent of the collection remains almost "unexplored". Experiments in minerology, petrology, geochemistry, physical properties, biochemistry, and other fields will keep investigators busy for years to come. Problem-oriented research using samples from a number of different Apollo sites are now being carried out. Many key pieces of information about early lunar history, not just a few surprises, probably remain to be discovered.

Scientists in Houston (the old Lunar Receiving Laboratory has given way to a permanent Lunar Science Institute, independent of the NASA space center) are responsible for the assignment of research tasks to hundreds of experimenters across the U.S. and in a dozen foreign countries. To insure the safety of the priceless rock collection, many samples were recently moved to another special storage facility at San Antonio, Tex.

Several recent developments have also made Earth-based observations of the moon more important. First, Apollo samples have provided "ground truth" corroboration for speculations based on telescopic observations. Second, new astronomical methods allow faster exposure times and better resolution of moon photography from Earth. The localized Apollo samples can be extrapolated to most of the visible half of the moon with these Earth based techniques.

Terrestrial exploration and experiments also have a new importance to understanding processes on the moon and other planets. For example, tiny glass spherules found in Apollo samples were at first thought to have come from deep inside the moon, transported to the surface by hypothesized volcanic activity. But recent geological research has revealed similar beads in rocks associated with a meteor crater on Earth (in India) implying a meteoric origin for the lunar beads as well. The Indian crater at Lonar was one of just a few terrestrial craters occurring in basalts like those on the moon.

Most of the exploration of the moon will continue to be carried out on Earth. Only one professional geologist (and 11 highly trained amateurs) has walked on the moon, but hundreds more conduct research on Earth. Besides the study of real lunar data, lunar scientists need more theoretical studies, terrestrial field trips, laboratory experiments, and comparisons with data from other planets.

The Soviet Union pioneered "on-site" exploration of the moon in 1959. Three robot probes launched that year scouted for a lunar magnetic field, photographed the hidden farside, and deposited a Soviet pennant on the moon. In 1966 and 1967, a dozen Soviet and American unmanned space vehicles soft-landed on the moon or went into orbit around it. New maps of the surface were prepared. Scientists charted the radiation and gravitational environment. The physical and chemical properties of the lunar surface were examined.

By 1968, both countries were nearing the finish line in the "moon race". The Soviets launched several unmanned Soyuz-type capsules around the moon and back to Earth — prototypes of a manned spacecraft which was to carry cosmonauts to the moon ahead of American astronauts. Then came the Christmas 1968 Apollo 8 triumph. The Soviets, rather than come in second, shelved their entire manned moon program and denied that it had ever existed.

The following year, the Soviets sent a series of automated lunar probes to explore the moon "without risk to human life". Although they boasted that their unmanned program was "10 to 50 times cheaper" than manned exploration, the robot shots actually cost about 1/3 as much as a manned shot, while returning less than 1/10 as much scientific information. Initial engineering problems were eventually solved after several failures, and the program began to meet with success. Between 1970 and 1972, two spacecraft scooped up a few ounces of lunar soil and returned to Earth. Two other vehicles deployed remote controlled "Lunakhod" moon buggies which rolled across the surface for several miles, photographing and measuring everything in sight of their robot eyes. A fifth probe did not land, but carried out scientific studies from orbit.

The Soviets began a new phase of robot moon shots late in 1974 with the flight of the Luna 23 orbiter and the Luna 24 lander. Although the attempt to retrieve a third load of lunar soil samples failed because of a rough landing, some communications relay tests between the lander and the orbiter vehicles presage an exciting new lunar experiment: a landing on the back side of the moon.

On the western edge of Oceanus Procellarum lie the craters Schiaparelli in the foreground — about 15 miles (24km) across, and 1-1/4 miles (2km) deep — and Seleucus on the terminator. Seleucus is 27 miles (43km) in diameter, and its walls rise about 2,300 feet (750m) above the mare surface. The mare surface is covered with a sprinkling of small craters, wrinkle ridges, and gentle undulations — a dramatically different surface than typical cratered highland surface. NASA photograph AS15-93-12633.

The American probe Ranger 4 had smashed onto the backside of the moon in 1962, and some of the lunar orbiters were crash landed there at the end of their photographic missions, but no active landings have ever been made because of the problems of communications with Earth. With a relay satellite in orbit high overhead, a Soviet spacecraft could stay in contact with technicians on Earth even on the back side of the moon. A moonscoop drill, or a roving moon cart, could easily be controlled with this relay system.

The hidden side of the moon was first photographed by the Soviets in 1959, following three American failures in 1958. It was surprisingly different from the visible side, with none of the wide expanses of lava filled mare basins. Unmanned probes mapped it in the mid-1960s, and manned Apollo ships made extensive surveys between 1968 and 1972. The return of actual rock samples would be an important scientific feat, which the Soviets will probably attempt sometime in 1976.

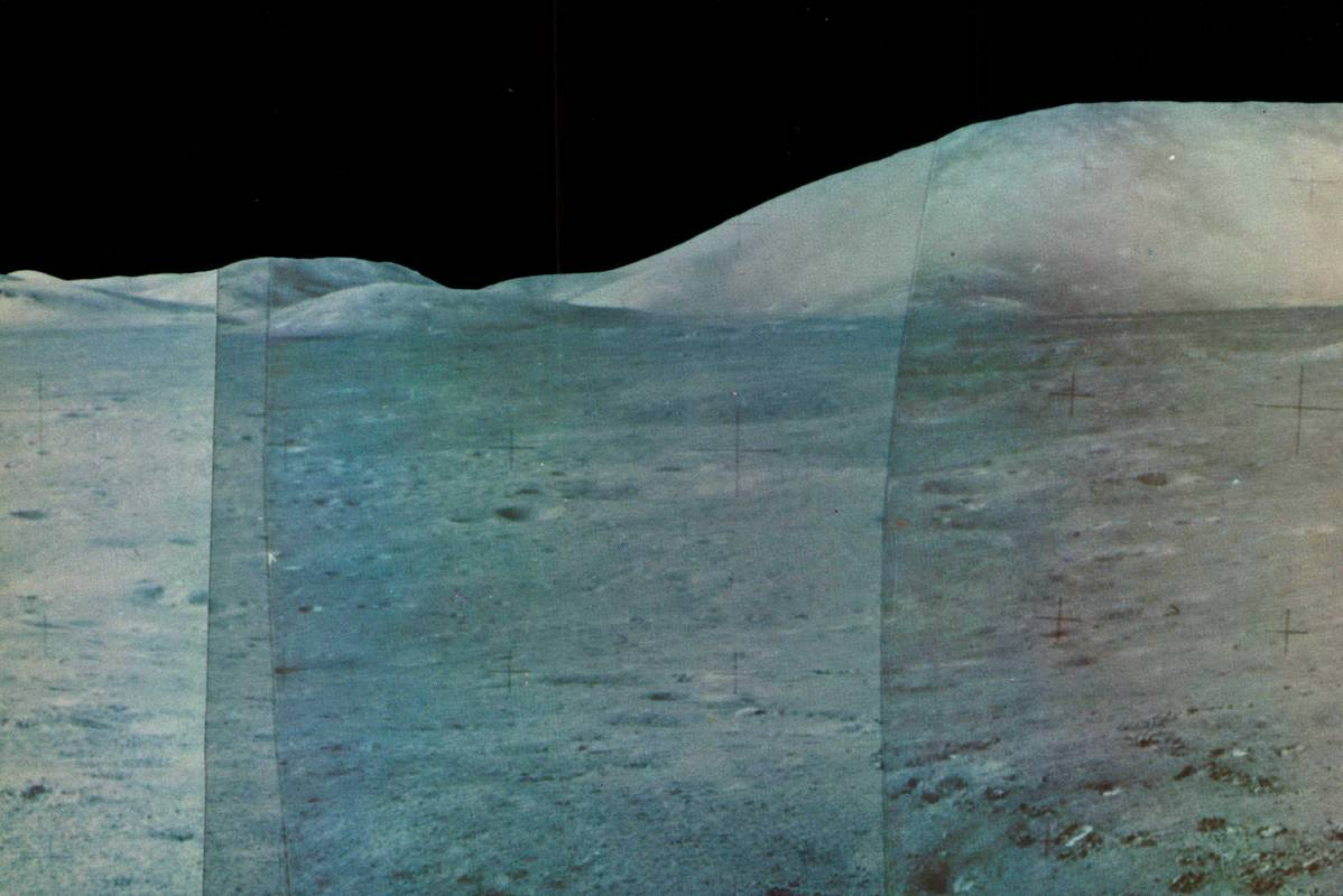
Meanwhile, data from the four surviving ALSEP stations continues to pour into NASA's Deep Space Network. The signals are taped and mailed to the dozen principal investigators who are still working on the experiments. Besides receiving data transmissions NASA engineers also occasionally monitor each ALSEP s performance, looking for problems or just doing normal maintenance tests.

Although there are no definite American plans for new moon flights, NASA would like to launch an unmanned lunar satellite in 1980 which would continue the surveys begun on the last three Apollo flights. Orbital x-ray and gamma ray experiments, as well as more detailed readings on the moon's magnetic and gravitational fields, can extend the usefulness of incomplete Apollo data and fill in some of the present gaps in orbital data now on hand. Correlations between radiation and gravitational anomalies with visible surface features were discovered by subsatellites left behind by Apollo spacecraft, and scientists want to examine this phenomenon more closely.

As part of the era of space cooperation between the U.S. and the USSR, moon rock samples have already been exchanged. An American experiment hitchhiked into orbit on a Soviet biosatellite in late 1975, and American instruments may also ride to the moon on board a Soviet Luna moon orbiter. This arrangement in joint lunar exploration would save NASA the cost of a Thor-Delta booster, and it would be another rewarding step along the road of international cooperation in space exploration.

Once the U.S. Space Shuttle becomes opera-

From distant views by telescope, astronomy has moved its vantage point to the surface of another world. Apollo 17 astronauts took this panoramic view in the Taurus-Littrow Valley during a sample collecting field trip across the lunar surface. Central in the background is South Massif; to its left is Bear Mountain. The Lunar Rover — the 20th century extension of Galileo's telescope — is almost lost amid this vast and desolate moonscape. NASA photographs AS17-146-22383 through -22392.



tional in the early 1980s, new unmanned lunar missions can be carried out. Surface roving vehicles and selected sample returns could be made. With the new "Space Tug" orbit-to-orbit booster available in 1985, renewed manned exploration could take place by the second half of that decade.

For the present, the data and equipment on hand is sufficient to keep today's lunar scientists busy for years. A tremendous amount about the moon, and by comparison about Earth, has been learned from Apollo results. Some of the most important questions being studied are how to ask the next round of questions on a new generation of moon flights after 1980. Newly discovered data continues to raise these kinds of fascinating questions.

For example, measurements of the precise Earth-moon distance are far more important than just for refining a number to put in an almanac. Ranging accuracies are now possible to within centimeters, but the current bottleneck is in the computerized mathematical model which explains just how and why the moon responds to the torques of terrestrial and solar gravity. Determination of this behavior leads to conclusions about the moon's moment of inertia, which describes the variations of the moon's density with depth, which in turn has strong implications about the origin and formation of the moon and other planets.

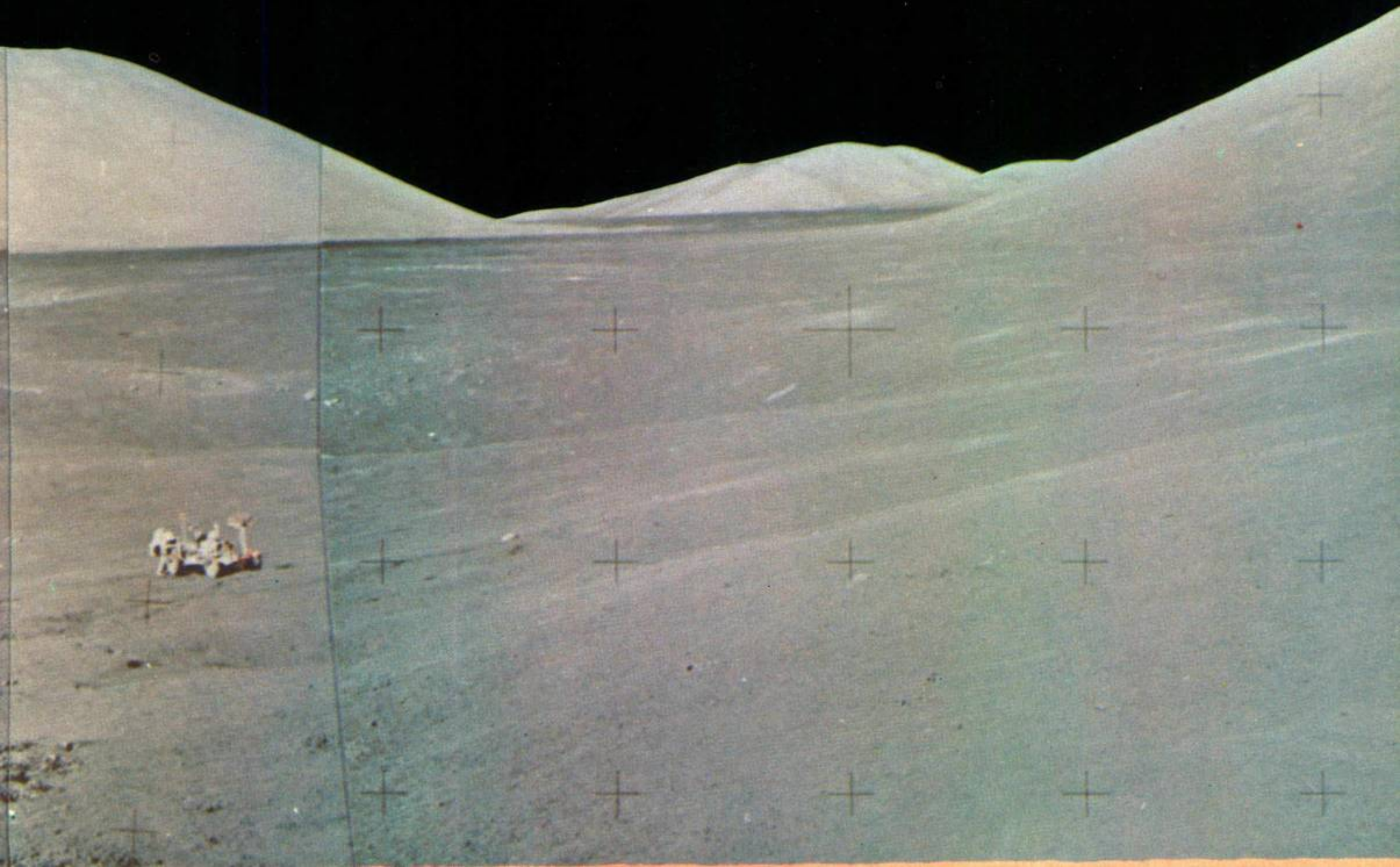
Measurement of continental drift, which averages a few centimeters a year, will be facilitated by lasar ranging stations on different geographic "plates". NASA is building a laser station high atop Mount Haleakala in Hawaii for just this purpose.

The passive seismometers left behind by Apollos 12, 15 and 16 will continue to report on the timing, intensity and location of moonquakes. This information — vital to understanding the internal structure of the moon — is something of a bonus left by Apollo. Furthermore, the seismometers record the impact of meteorites hitting the surface, thus making the entire moon a giant meteor detector.

Continuing seismic data is important because of the intriguing periodicity of the seismic readings. Besides an obvious monthly cycle, there is an apparent seven month and a theoretical six year variation. Some of the repeating quake locations seem to be dying out and others seem to be beginning. This suggestion of dynamic geological changes within the crust of the moon is puzzling. Long-term monitoring is necessary to understand such processes.

NASA anticipates the need for at least five more years of ALSEP activity. All four surviving ALSEP stations are in good shape, although their isotope power sources have degraded slightly and some individual experiments have failed. The study of Apollo samples, too, will entail at least a decade's more work.

Thus, exploration of the moon continues. Data comes in from lunar satellites, from the lunar surface, and from 100 laboratories. While the headlines come from beyond Jupiter, Earth's nearest neighbor is not being ignored.



GAZER'S GAZETTE

The Last Quarter Moon

by
Richard Berry

If you awaken before dawn on a clear morning about a week after full moon, look due south; you'll see the last quarter moon hanging in the sky.

The first quarter moon — on the meridian at sunset — is a familiar sight to telescope users, while the last quarter moon — an equally fascinating sight — is largely unfamiliar since you have to get up before dawn to see it. Even with the naked eye, you'll see they're not the same. The western half of the moon's visible face (the part you see at last quarter) is largely covered by maria — mostly Mare Imbrium and Oceanus Procellarum — giving it an entirely different appearance than the cratered highlands so prominent at first quarter. (The word *mare*, Latin for "sea", is applied to many of the sealike features on the moon.) Of course, your favorite craters from the waxing gibbous phases are visible, but are seen in a new light. The walls you're used to seeing in dark shadow now shine in the direct glare of late lunar afternoon sunlight.

Maria surfaces are about half as reflective as highland surface. So much mare surface is exposed at last quarter that it is considerably dimmer than first quarter! Although it is predawn on Earth, sunlight on the moon is in what you would call "late afternoon". The effect of looking at the dimmer, mare covered moon — if you're used to it — can leave you wondering if you're seeing the same satellite.

Copernicus is perhaps the last quarter's number one attention-grabber; it appears isolated on the western exposure of mare with its rays crossing hundreds of miles of their dark surfaces. Copernicus rewards close study. Even with small telescopes, the central peaks are visible. Along the interior wall, the original walls seem to have collapsed and slid down, forming multiple interior scarps and terraces. Outer walls and areas around the craters often show the soft, "rumpled" appearance which material ejected from craters seems to have. Recognizable ejecta blankets are common around the newer craters.

With a good six inch telescope, you can see a string of craters northeast of Copernicus, about 1-1/2 times its diameter away. These are secondary impact craters, where some of the "stuff" thrown out of Copernicus landed. The line they form is particularly easy to spot, but all around Copernicus are more tiny secondary craters.

Farther northeast is Eratosthenes, older and smaller than Copernicus. In fact, with steady seeing conditions, some of Copernicus' rays and secondary craters are visible on the flanks of Eratosthenes. Like Copernicus, Eratosthenes has an asymmetric, noncentral central peak. A crater just south of Copernicus, Fauth, actually consists of two small craters — one a bit bigger than the other — looking rather like an old-fashioned keyhole in the lunar surface!

The Apennine Mountains surround Mare Imbrium. Late lunar afternoon sunshine illuminates the high walls of the Apennine front — a cliff rising irregularly from the mare. Running just inside the line of cliffs is the Apennine bench formation — perhaps an interior ring of hills that is almost flooded by the lavas of Mare Imbrium. The Apennines may be part of the ejecta blanket of the impact that eventually resulted in Mare Imbrium. Close to the mare, the Apennines look rugged, but become smoother the farther outward you look.

How high is the Apennine front? From the shadows it casts, it stands about five miles above the surface of the Mare. Although it looks jagged, the Apennine front appears as a series of smoothly rounded hills in the background of many Apollo 15 photographs taken at Hadley Hill.

Prominent on Mare Imbrium is Archimedes, a 43 mile diameter flooded crater located adjacent

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Half a day before first quarter moon, the terminator is very slightly convex. This shot was taken with the 12 inch f/9 Newtonian reflector of the Milwaukee Astronomical Society at Newtonian focus, with Ektachrome-X film, at 1/30 of a second. The peaks farthest north of the Apennine Mountains are just catching their last few hours of sunshine before the two week long lunar night. Note the immense expanse of mare surface. Photograph by Chris Hesseltine.

The Man-of-the-Light-Year at Meade Instruments is Nicholas-Louis de Lacaille

It was he who first espied 87 naked eye stars in the mid-18th century South African skies. What's more—he resisted the temptation to name them for some time-worn demi-gods and -goddesses. He is very special to us not because this was a landmark sighting in the history of astronomy. Hardly. Rather it's because he made a constellation of a nondescript array of stars and called it "Telescopium".

Perhaps it seems a bit obvious for a telescope designer/manufacturer to capitalize on a sprinkling of stars that you have to force yourself to see as a telescope constellation.

Well, we don't blame anyone these days for being advertising-shy. But this is the way we happened onto our Man-of-the-Light-Year.

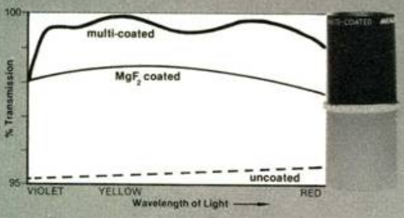
At Meade Instruments we're always taking a long, hard look at our products. At the way they meet the stringent requirements of serious amateur and professional astronomers. At the way they assemble into finely-meshed instruments under the gun of dead-eye tolerances. At the way they smoothly integrate themselves into our own telescope systems and even enhance the finest systems built by our competitors.

Like Lacaille, we are always on the alert for new and more exciting constellations that can be made with our components. This takes some doing when so many of our fine instruments are stars of such impressive magnitude that we might overlook the larger picture. Whenever this is about to happen we will get a call or visit from a customer who has been scanning our ads and not seeing the system for the components.

Together we make a sighting of his own Telescopium—the optimum interface of several Meade components. Our customers tell us that a helpful word or two of our technical counsel has saved them countless hours of unproductive ad-scanning.

Taking another leaf from Lacaille we call your attention to the system orientation that governs all our design and manufacturing—of everything from a color filter to a full-blown refracting telescope.

Our exclusive Meade Research-Grade Orthoscopic eyepieces are a case in point. To begin with, they are superior 4-element optical systems in their own right. As such, they are unsurpassed for color correction, resolution, and flatness-of-field. The lenses are figured to incredibly exacting tolerances and are 5-layer Multi-Coated to maximize light transmission and increase image contrast. The extent to which Multi-Coating enhances light transmission can be readily seen in the comparative curves.



For another thing, all six of our Research-Grade eyepieces are precisely parfocal: the observer need not re-focus the image each time he switches from one eyepiece to another.

And oh — a belated thanks to you, Nicholas-Louis de Lacaille. May your star shine brightly in the astronomer's firmament. Without you, we couldn't have made such a telling point about Meade optical systems.

PRODUCT DATA

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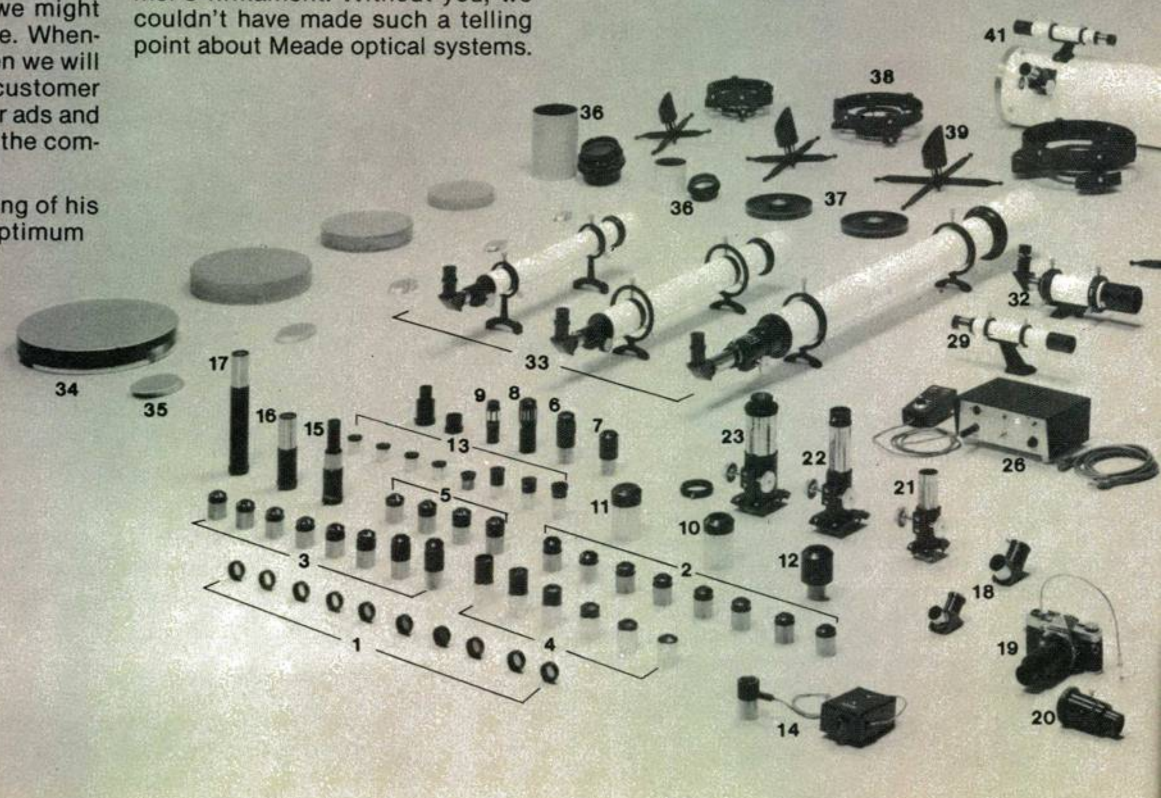

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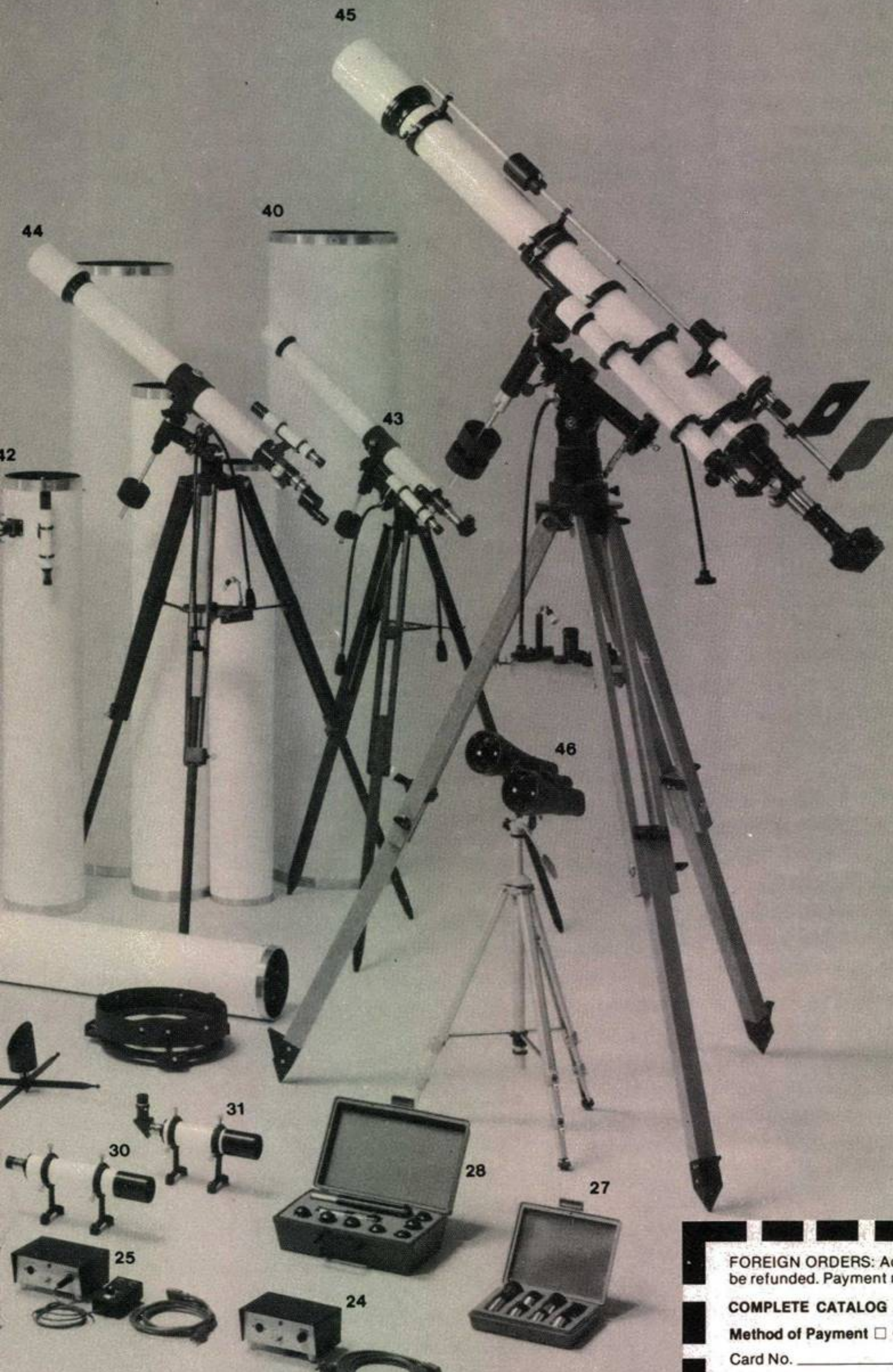

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to some very mountainous terrain, and perhaps part of one of Mare Imbrium's primordial rings of mountains. Archimedes' lava covered floor has a few tiny craters on it.

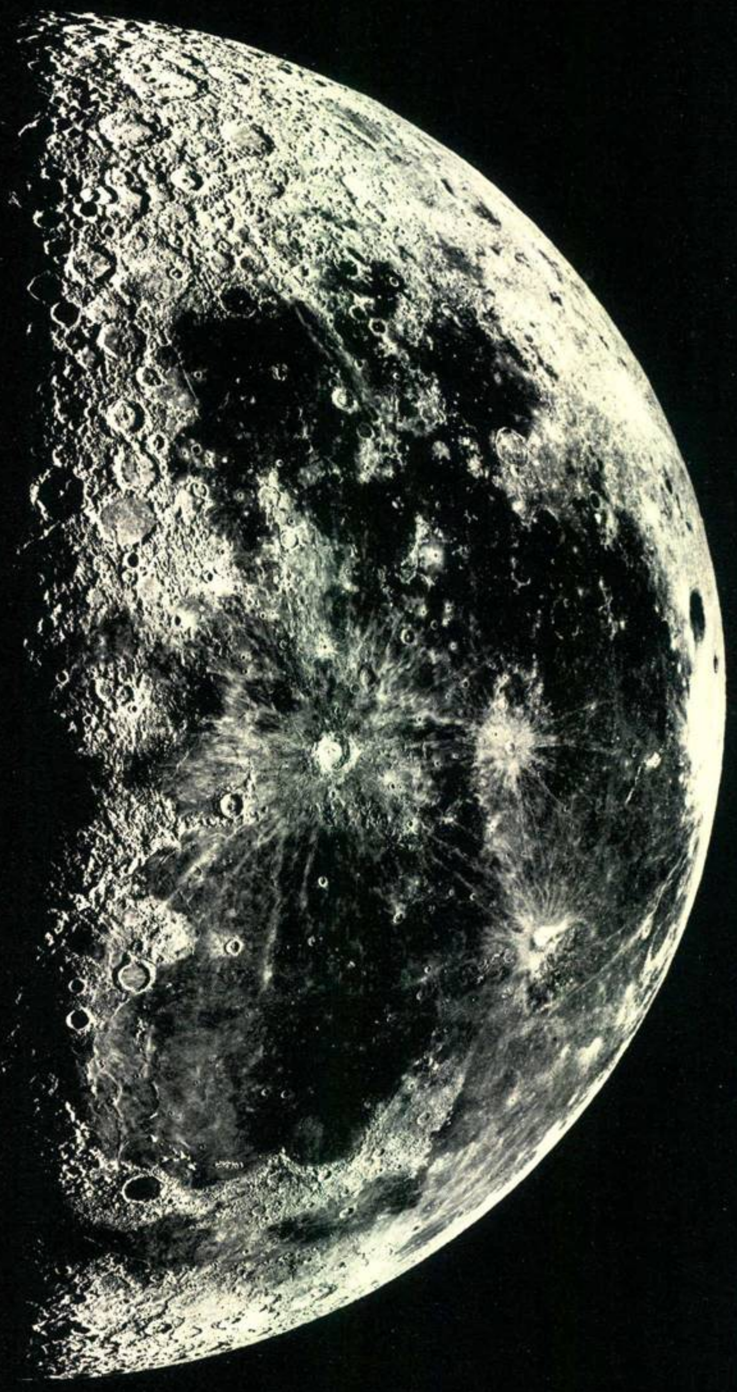
Between Archimedes and the Apennines is a small, rather rough, lava flooded pool whimsically called Palus Putredinis (Marsh of Decay). A number of rills, radial to Mare Imbrium, cross Palus Putredinis while more rills and mountain chains run concentric to the Apennine front.

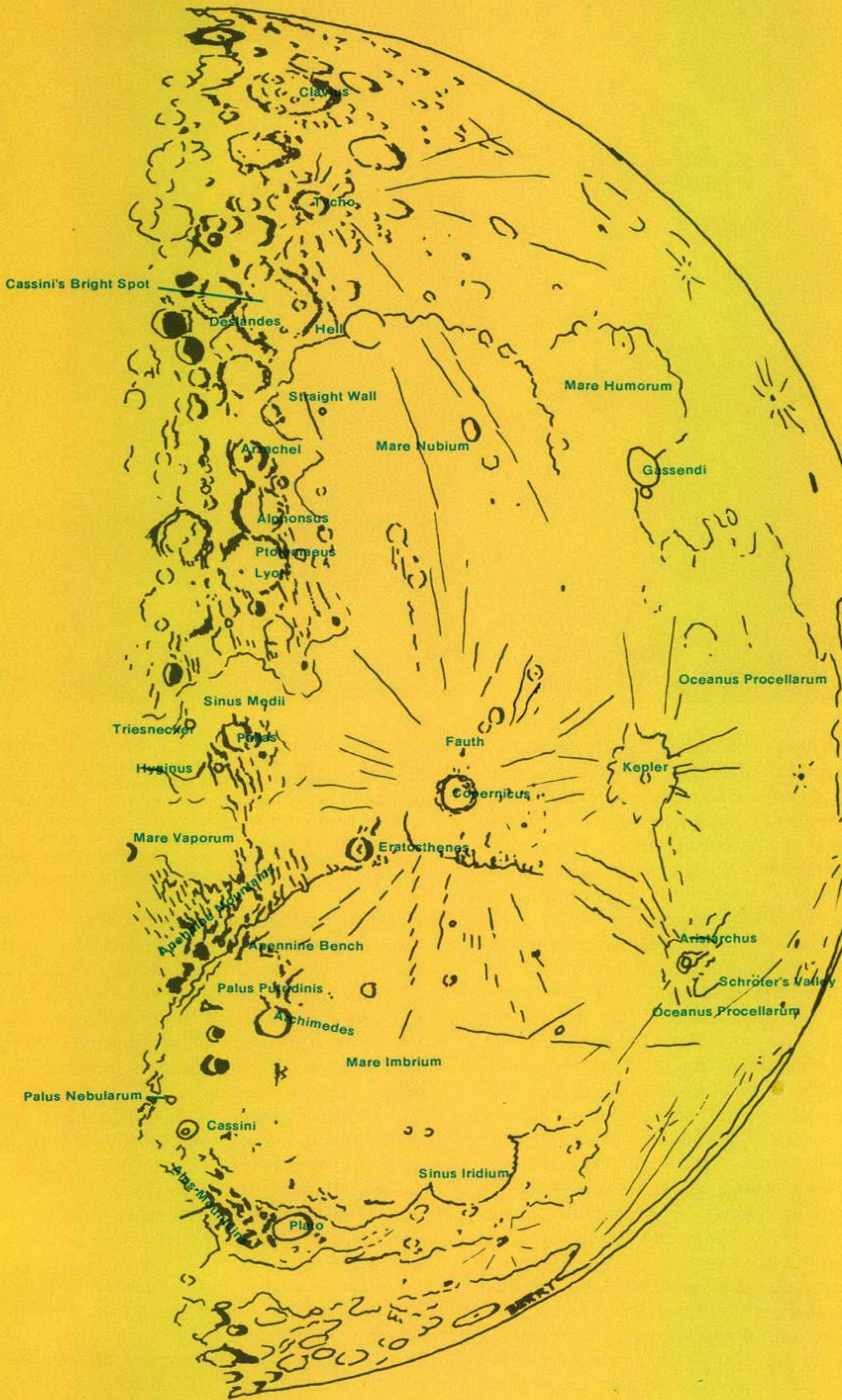
Farther north, the fresh crater Aristillus (34 miles in diameter) and the degraded crater Cassini make a striking contrast. At last quarter, both are illuminated by the setting sun. Aristillus' ejecta blanket stretches across the mare surface while Cassini has narrowly escaped becoming a ghost crater. Two small craters have formed inside Cassini. The rough mare surface near Cassini is called Palus Nebularum (Marsh of Clouds). The mountain peaks that protrude from the mare lavas known as Pico, Piton, the Spitzbergen and Teneriffe Mountains catch the sun's rays hours after the sun has set on the mare.

The eastern side of Mare Imbrium abounds in wrinkle ridges, and they are really quite spectacular under low illumination. At least a dozen can be seen between Archimedes and Plato at last quarter. As the terminator sweeps west, you'll see that ridges are common over the mare surfaces, usually paralleling the mountainous rim of the mare. Wrinkle ridges are related to the volcanic formation of maria, but their precise relation is still uncertain. They are very low relief — a few hundred yards high and many miles wide. If you moonwalked across one, you probably wouldn't be aware of its slope.

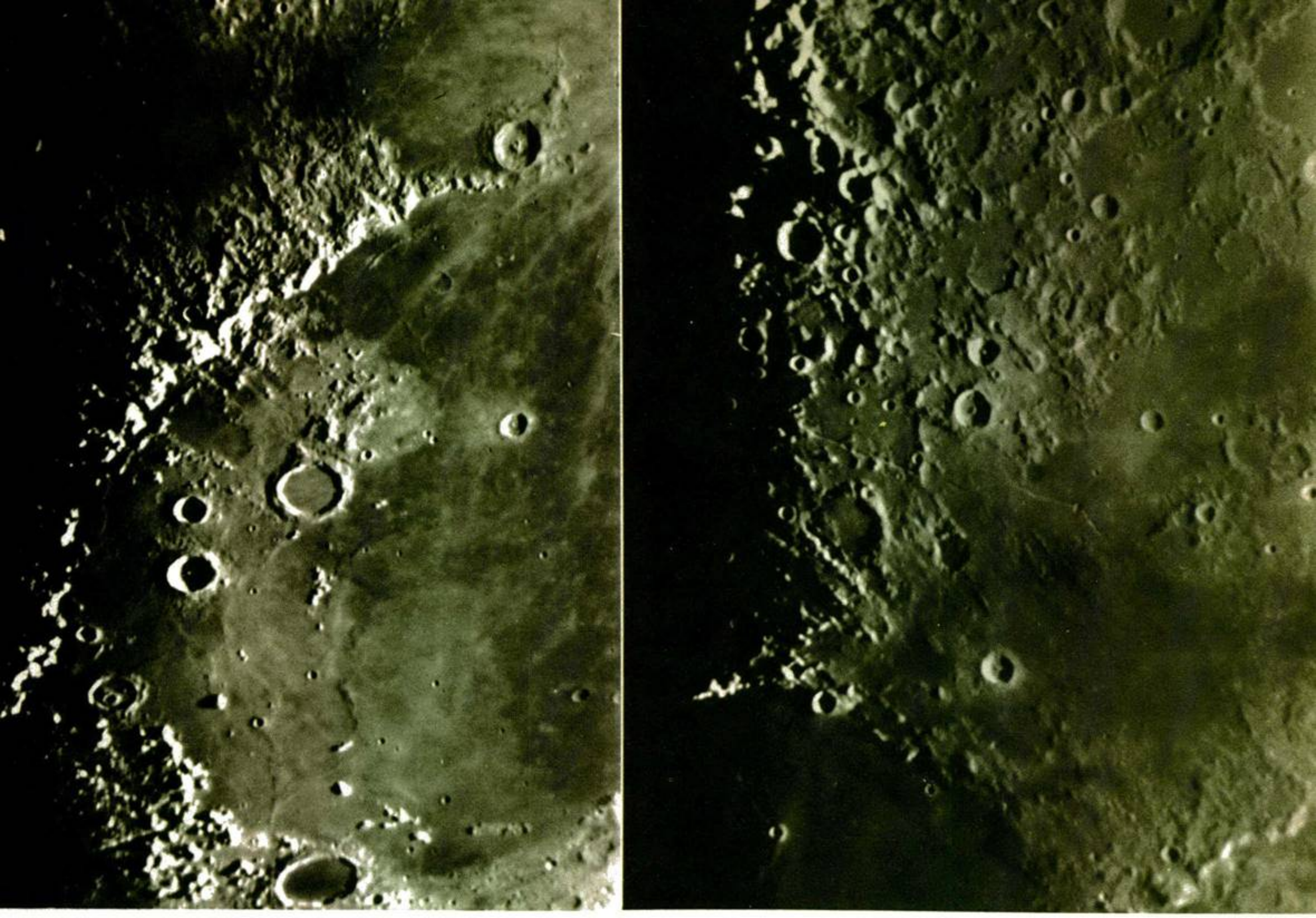
Plato, a dark oval 56 miles across, located in the lunar Alps north of Mare Imbrium, was a source of controversy among British observers around the turn of the century. The craterlets on the lava covered floor of Plato seemed to become visible at some times but not at others. Some observers claimed that Plato was filled with fog or mist, obscuring them. The same is true today: Atmospheric seeing, lighting and telescope quality cause the craterlets to be hidden sometimes. A good six inch reflector shows them under the illumination of the last quarter moon. Plato's interior walls have slumped, especially along the eastern side where part of the crater's rim looks double. Exactly how Plato, Archimedes, and other craters "filled up" without noticeable channels leading the maria is not known.

You could spend the rest of the rapidly ending night poking around Mare Imbrium, but there's more to see on the southern lunar hemisphere. Once over the Apennine Mountains, you'll cross Mare Vaporum (Sea of Vapors) which displays its wrinkle ridges well at low lighting, south to Sinus Medii, an impressive system of ridges and rough ground. Triesnecker, in the middle of Sinus Medii, is surrounded by delicate rills that crisscross the whole sinus and also cross each other. To the north, a small




Clavius
Tycho
Cassini's Bright Spot
Deslandes
Hell
Straight Wall
Mare Humorum
Arzachel
Mare Nubium
Gassendi
Alphonsus
Ptolemaeus
Lyot
Oceanus Procellarum
Sinus Medii
Triesnecker
Pallas
Fauth
Hyginus
Kepler
Copernicus
Mare Vaporum
Eratosthenes
Apennine Mountains
Apennine Bench
Aristarchus
Palus Putredinis
Schröter's Valley
Oceanus Procellarum
Archimedes
Mare Imbrium
Palus Nebularum
Cassini
Sinus Iridium
Alps Mountains
Plato
BERRY

Lick Observatory Photograph/Artwork by Richard Berry



Left: Mare Imbrium, Archimedes, and the lunar Apennines near the end of a two-week lunar day. Past the terminator, a few peaks catch the last rays of the sun; their bases are already in shadow. Note the prominent wrinkle ridges on the mare surface. Right: In this view taken a day before last quarter, the general structure of Sinus Medii and Mare Vaporum reveal photographically what the eye sees best under the dramatic low light of the next day. Photographs by E. Ken Owen.

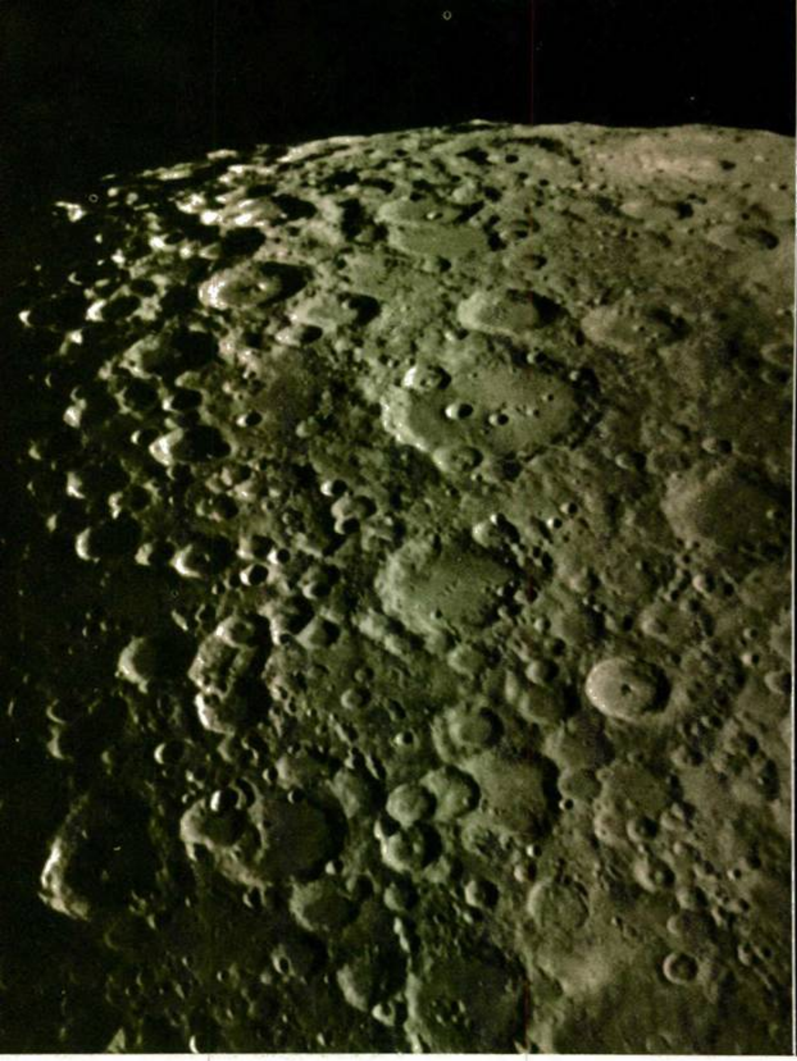
crater named Hyginus straddles the Hyginus Rill. The rill is about 120 miles long, 2 to 4 miles wide, and up to 1/2 mile deep. The terrain enclosed by the rill looks pretty dull except when the rising or setting sun brings it to life; only then do you see intricate ridges and troughs on the mare surface. The Hyginus Rill may be a *graben* — a fault where a block of ground has slipped down.

The little "island" of light colored terrain containing the crater Pallas is interesting as it contains grooves and mountains that point back toward the middle of Mare Imbrium. Perhaps they are gouges cut by giant boulders from Mare Imbrium. Farther south in the highlands around Apparchus and Ptolemaeus, more intriguing linear features cut across the walls of the craters, seeming to control the topography of the highland. Two of Ptolemaeus' sides (Ptolemaeus is not round, but hexagonal) are aligned with these features, which has raised doubts that it is not an impact crater, but perhaps a volcanic feature of some kind. Nevertheless, Ptolemaeus, 87 miles in diameter, has a lava covered floor with lots of interesting pits and dimples. Lunar sunset takes about three hours to cross Ptolemaeus' floor and is worth watching if you ever get the chance.

The small crater *inside Ptolemaeus* is Lyot. Just north of Lyot is a saucer shaped depression quite unlike a crater, which is best seen under low angle lighting near the terminator. Two more craters attached to Ptolemaeus, Alphonsus and Arzachel form a conspicuous trio. Arzachel is in the best shape (thus presumably newest), while Alphonsus is rather eroded and run down. Alphonsus has been strongly affected by the Imbrium Basin trenching — presumably formed before Imbrium. Arzachel is free of such effects, and was apparently created after the Imbrium event.

On the surface of Mare Imbrium, near the crater shore, is a very spectacular fault in the lunar surface known as the Straight Wall. At last quarter, the sun illuminates the wall; you see it as a bright line. The cliff may look steep in a telescope, but is actually a fairly shallow slope. It is definitely worth hunting around for.

Farther south lies a mountain-walled plain, 130 miles across, called Deslandes. Deslandes is a battered object, intruded on by Walter in the southeast, mountains to the north, and defaced by numerous small craters. At full moon it is crossed by rays from Tycho, just to its south. The low illumination at last quarter reveals lines of craters, rough



Left: The cratered southern highlands of the moon seem like a jumble of blasted rock until learning their names imposes order. Clavius makes an excellent starting point; it is always recognizable when exploring this area by telescope. This shot was taken with a 10 inch home built reflector. Photograph by E. Ken Owen. A few days after last quarter, vast expanses of mare lie along the terminator. Aristarchus stands in the middle of Oceanus Procellarum. Photograph by Steve Reed.

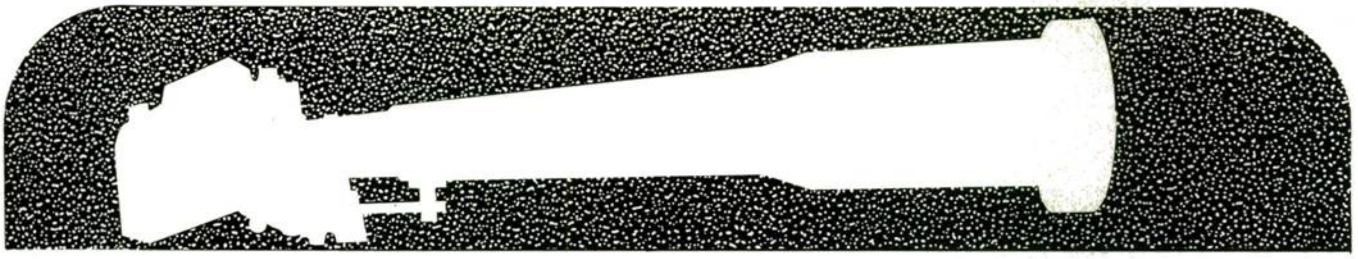
spots and depressions. An interesting feature in Deslandes is Cassini's Bright Spot — a small, but exceedingly bright, ray crater that dominates the area around lunar noon. As late as one day before the terminator reaches it, the spot is still conspicuous. Cassini, a 17th century observer, discovered it and thought it was a cloud. Since then, various confused reports of his observation have filtered through lunar literature.

Another great mountain-walled basin, Clavius, lies farther south. Its distinctive pattern of interior craters makes it recognizable. Clavius is better preserved than Deslandes, though its walls are breached by two large craters and peppered with smaller ones. It comes as a shock to the telescopic observer to see spacecraft photographs of Clavius from overhead — Clavius is round! Even though a telescopic observer knows it is round, somehow the round Clavius doesn't really seem to be Clavius.

A few days after last quarter, the terminator crosses Mare Imbrium and Mare Nubium leaving the waning crescent covered with the huge expanse of Oceanus Procellarum, tiny Mare Humorum, and a trace of northern and southern highlands — a strange view for those accustomed to heavily cratered terminators. The major attractions are Gassendi in the south and Aristarchus in the north, and it would be hard to find a more complimentary pair. Aristarchus is new, and at nearly all illuminations is just about the brightest thing on the moon. Schröter's Valley, probably a lava flow channel, is slightly north and west of the crater; the unusual bright markings near the crater make it worthy of careful study. Gassendi is located on the northern ruin of Mare Humorum, and has been "worn down" extensively. The interior is full of cracks and hills that can be seen with a six inch reflector when the seeing is good (not too common for a crescent moon). Its northern half is partially flooded and the walls are broken by the lavas.

A final interesting feature is Kepler's Rays which catch the rays of the setting sun. Rays usually disappear near the terminator, so Kepler is an exception.

You'll find it worth the effort to get up an hour or two before the sun and give the last quarter moon a careful examination. Predawn hours can be very peaceful amid the gentle chorus of waking birds announcing dawn. And for the rest of the day, you can have the good feeling of knowing you started your day doing something worthwhile.



Developing B&W Astrofilms

by

David Hudgins

Getting your first successful constellation shots back from the film processor may have seemed exciting, but it won't match the thrill of bringing photographic images to life yourself. Developing your own film is doubly rewarding; not only is it just plain fun, but it can make it possible for you to record stars, planets and nebulae as you never could before. Why? By processing at home, you can use powerful developers and specialized films that commercial processors simply won't touch.

Drugstore processing is oriented toward ordinary films and the subjects typically found in family snapshots. Getting the most from astrophotos means developing film to higher speed and contrast than desirable for snapshots. Special processing is easy if you do your own developing, but you won't find a commercial developer who can do it for you at a reasonable price. The old adage, "if you want it done right, do it yourself" surely applies to the astrophotographer.

Developing B&W film is surprisingly easy; the basic steps are simple, and manufacturers make a variety of inexpensive equipment and photo chemical package sizes well-suited for home processing. For about $15 and a trip to your local camera shop or large discount store, you could be developing your own film tonight.

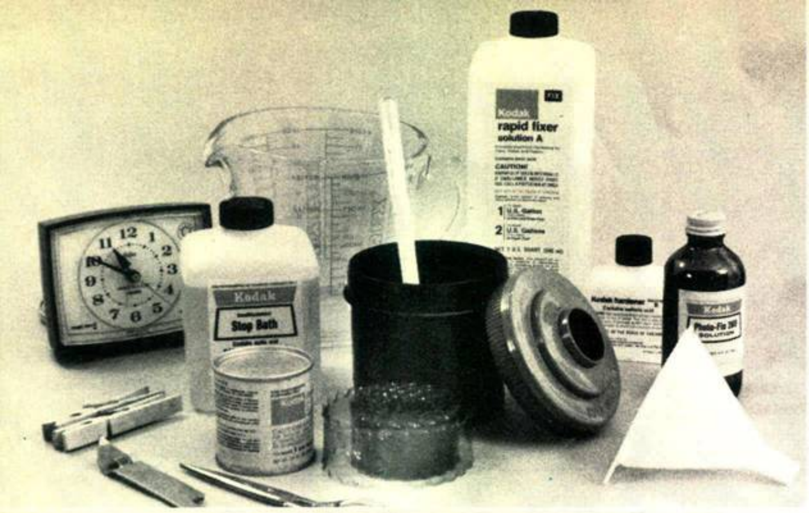
To do your own film processing, you need to understand what is going on *inside* the film when it's exposed to light and developed. While many different black and white films exist, all work in the same way.

Films consist of two basic parts — a flexible plastic film base and the emulsion. The emulsion is the light sensitive layer that forms the shaded images on the developed film; it is really the only thing that makes one film different from any other. An emulsion is made up of billions of tiny crystals of silver halide suspended in a transparent gel. Films differ in the size and number of silver halide crystals put in the emulsion as well as exactly how they are processed in manufacturing. The mixture of gel and crystals is coated as a thin layer over the plastic base, which provides mechanical support for the emulsion.

When exposed to light, a tiny portion of each silver halide crystal is converted to pure metallic silver. This change is invisible to the eye, but makes it easy for chemicals called *developers* to convert the entire silver halide crystal into pure silver. After development, the tiny grains of silver appear dark and remain suspended in the transparent gel. The more light that strikes a particular area of the emulsion, the greater the number of silver halide crystals that are altered to the point that the developer can turn them black. The more black silver grains there are in the emulsion, the darker and more opaque it appears.

What about those areas of the emulsion that are not exposed to light? The developer has relatively little effect on these areas, but the unchanged

The major steps in developing your own film can all be done at home with very little special equipment. (1) Your equipment will include (left to right) a clock, clothespins, a can opener, scissors, developer, stop bath, a measuring cup, thermometer, film tank, its reel and cap, fixer, funnel and Photo-Flo. (2) In total darkness, use a can opener to remove the end cap from the film cassette. (3) With a Kodacraft tank, wind the film into the apron, or (4) with a reel, wind the film onto the reel. Note that the film is "bent" slightly by the fingers. (5) Begin processing by pouring the developer into the tank, (6) agitating the tank as the manufacturer instructs. After developing, the developer is poured off, and stop bath poured into the tank. After the stop bath is poured off, fixer is poured in. After fixing, (7) the film is washed under gently running water. You should make sure that the tap won't unexpectedly change temperature. (8) Finally, the film is hung up to dry in a dust-free place such as a bathroom.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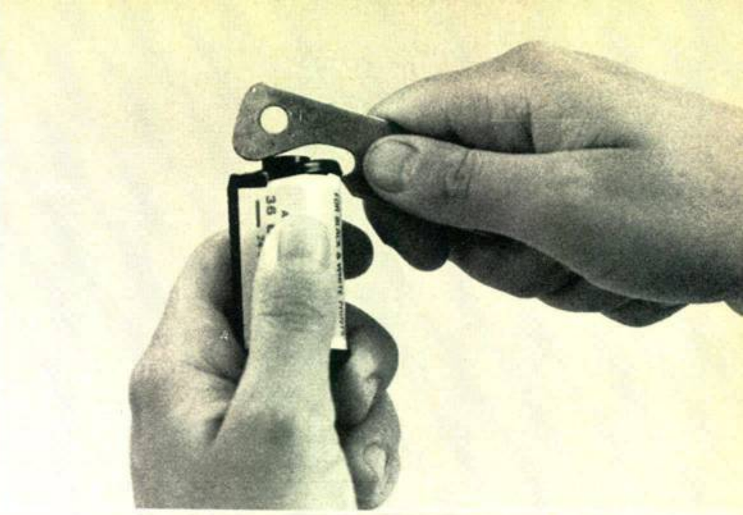

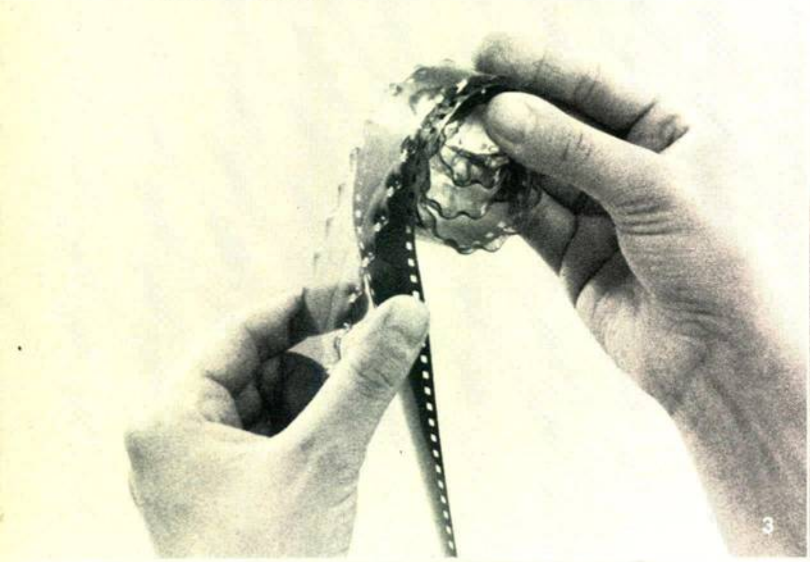
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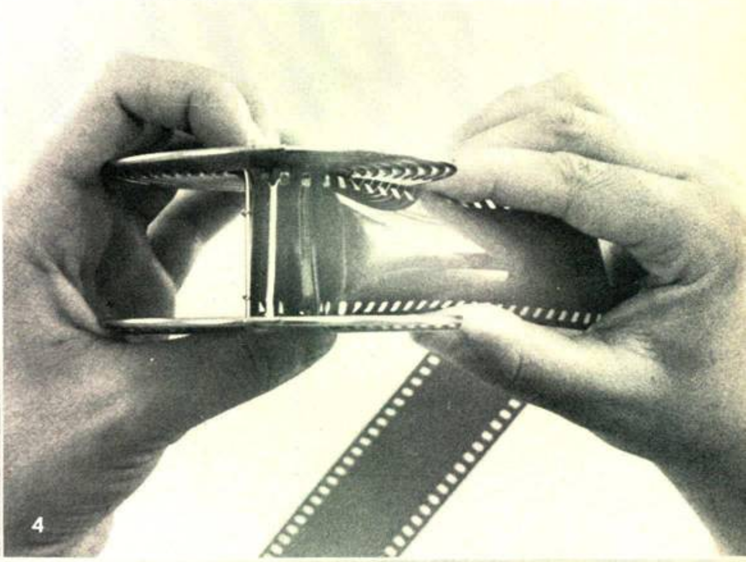
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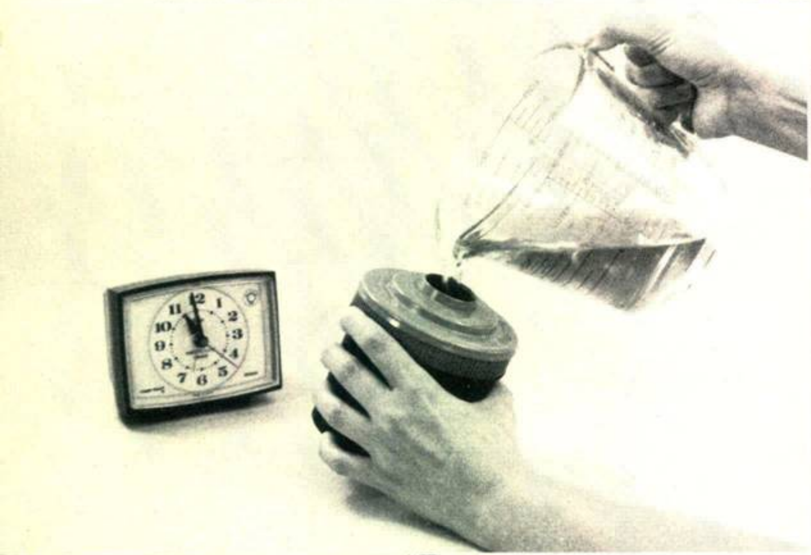

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silver halide crystals cause the emulsion to remain a milky white color.

In the next step, a chemical called a *fixer* is used to dissolve the unexposed silver halide crystals, thus removing them from the emulsion. After fixing, unexposed areas of the film are clear while the exposed areas are black. Because the tones are reversed, processed films are called *negatives*. To complete processing, film must be washed (to remove chemicals absorbed by the emulsion) and hung up to dry.

The necessary equipment and chemicals are simple and inexpensive. First is a "daylight developing tank" — a small metal or plastic container that has a removable cover with a special hole in the top. The hole lets you pour various chemical solutions in and out without letting any light inside. Once exposed film is placed inside the tank, everything else can be done with the room lights on. Inside the tank, the film is held in a metal or plastic reel so that the photo solutions can freely reach the emulsion. Many different brands of daylight tanks are available, but the easiest one for a beginner to use is the Kodacraft by Kodak, which costs about $6.

The advantage of the Kodacraft over other tanks is the clever way Kodak overcomes the problem many beginners have in loading film into the reel. Since loading must be done in total darkness, it tends to be tricky using a stainless steel reel or the newer "walk-in" plastic reels. If the reels are not loaded properly, solutions will not flow freely over the film — thus causing areas to remain undeveloped. The Kodacraft solves the problem by using a three foot long piece of flexible plastic that Kodak calls an "apron", instead of the conventional reel. The film is simply rolled up inside the apron as shown on page 47. This operation is extremely easy even in the dark.

In the long run, though, the conventional reel works best, has lower contamination levels, and permits more uniform agitation. Whatever tank you buy, practice loading it under normal room light with a discarded length of film.

You will need a darkroom thermometer to measure the temperature of the photo solutions. A $3 alcohol thermometer is fine initially; you may later find the increased accuracy and readability of the dial type to be a good investment (about $10).

To store the processing solutions, you'll need four quart-size plastic bottles. You can buy these at the camera store, but refrigerator juice bottles cost less, work just as well, and often have large openings making it easy to pour the solutions in and out. You will also need clothespins and a clock or watch for timing. (See "Setting Up An Astrodarkroom", ASTRONOMY, June 1976.)

Photo Chemicals

You'll find the shelves of your camera store stocked with an impressive and somewhat intimidating variety of chemicals — in cans, bottles and packages! Many of these will produce very nearly the same results with your astrofilms, but you'll find four or five developers are especially useful to the astrophotographer. For the beginner, however, the choice of developer and other chemicals is quite simple. You should buy a quart size can or package of D-76 Developer, one bottle each of Kodak Indicator Stop Bath, Rapid Fixer, and Photo-Flow 200 wetting solution. Mix these chemicals with water according to the instructions on the packages, and set them aside for a few hours to let them stabilize at room temperature.

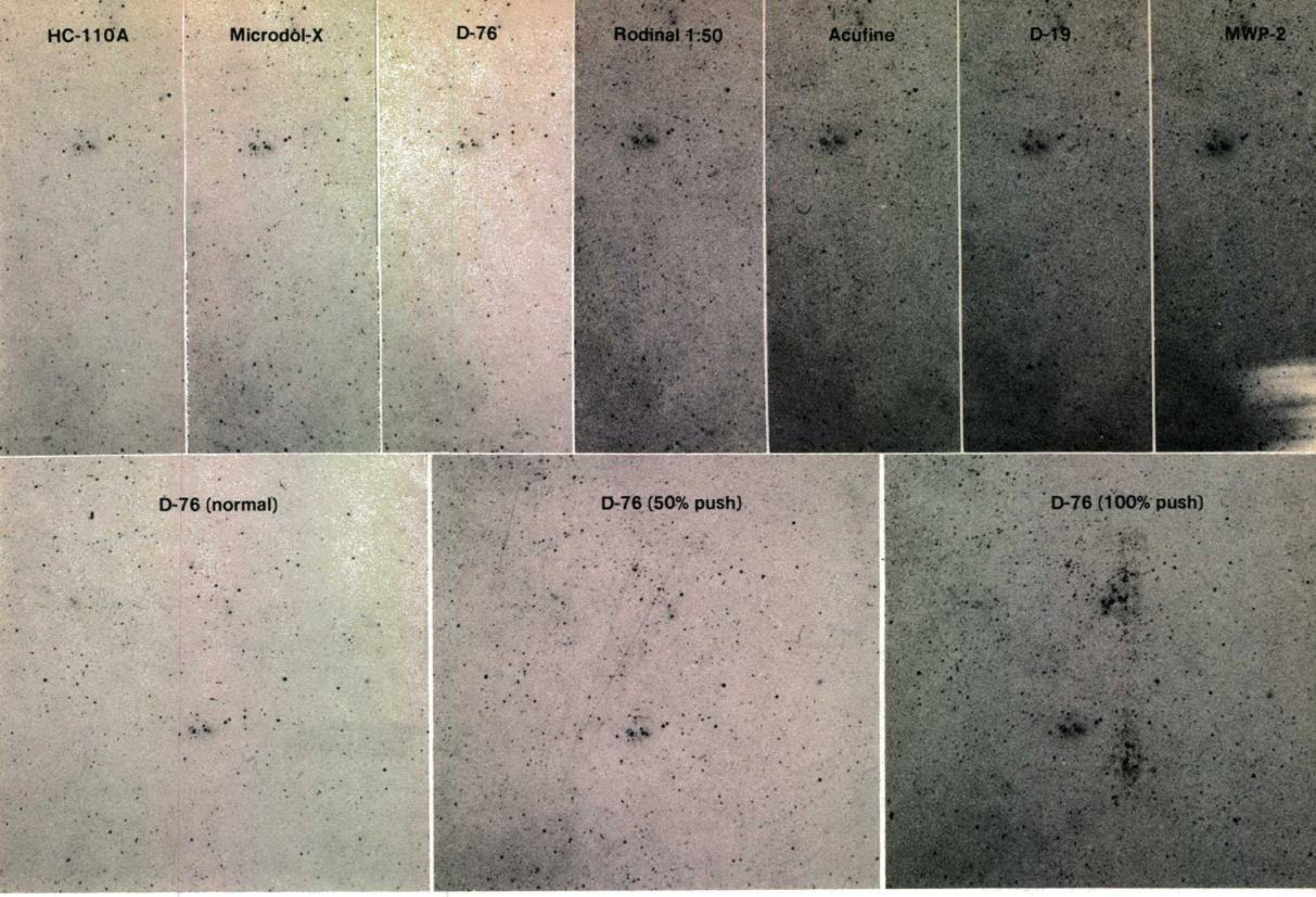
While it is certainly handy, you really don't need a permanent darkroom to develop black and white film. It is helpful to have running water, so a small table in the bathroom or space on the kitchen counter works well. Be sure to spread several thicknesses of newspaper or plastic sheeting over the work area, because spilled photo chemicals can leave stains. Remember that the first step — removing film from the cassette and loading it into the tank — must be done in total darkness. A windowless bathroom or closet often makes a good temporary darkroom. Towels placed along the bottom of the door will block any stray light. Make sure you have *total* darkness; if you don't see any light after five minutes, you can be sure that your film won't be fogged during the tank loading operation. (If no suitably dark place can be found in your home, you can buy a changing bag for $5 to $10 at the camera store. This is just a black cloth bag that you can stick your arms into, creating a miniature darkroom for opening the film cassette and loading the tank.)

Film Processing

After locating a darkroom, mixing the chemicals, and practice-loading the tank a few times, you'll be ready to actually develop that first roll.

STEP 1: With the lights on in your darkroom, arrange your tank, its reel, the tank cover, scissors and a can opener so that you can find them in the dark. Turn out the lights, check carefully for light leaks, and only then remove the film. Metal cassettes for 35mm film can be opened with a can opener by prying off one of the end caps; roll films are simply unwound and separated from their paper backing, and you simply break an Instamatic cassette apart. Follow the manufacturer's instructions to load the reel. Place the reel — with the film — into the tank, and screw on the cover. Now you can turn on the lights for the rest of the operation. Take a deep breath!

STEP 2: Check the temperature of the developer and other solutions. Processing is best done in the temperature range between 65 and 75 degrees Fahrenheit for most films. At temperatures above 75 degrees, emulsions become so soft that they are very easily damaged; at temperatures below 65 degrees, development is so slow that a great deal of time is wasted. In most places in the home, if you store your photo solutions you will usually find they



Top: Identical five minute exposures of the Lagoon nebula in Sagittarius taken with a 135mm telephoto lens are the subject for this comparison of developers, ranging from fine grain developers HC-110 and Microdol-X through Rodinal and D-76, to high power developers Acufine, D-19 and MWP-2. While the number of recorded stars increases, the more powerful developers are grainier. Bottom: By extending the development time, normal developers reveal more stars and nebulosity. D-76 was used at normal time, 50 percent push and 100 percent push, also on the Lagoon nebula. Photographs by David Hudgins.

are in the proper temperature range to process film. If not, you can raise or lower the temperature a bit by placing the bottles in a pan of slightly warmer or cooler water until you reach the proper temperature.

Once the developer is in the 64 to 75 degree range, make sure each of the other solutions is within five degrees of that same temperature. This will avoid damaging the emulsion by the rapid expansion or contraction it undergoes when subjected to solutions with large temperature differences.

After all your solutions are in the proper temperature range, refer to the instruction sheet that came with the film. On that sheet you'll find a table that specifies how long to process that film in several recommended developers. The development time indicated on this sheet is suitable for every day photography. These are the "normal" development times. They will produce *average* contrast levels and *normal* film speed with *minimum fogging* of the film due to overdevelopment. After checking the temperature of your developer, determine the proper development time from the instruction sheet.

STEP 3: Measure the proper amount of developer in a graduated cup according to the instruction sheet that came with your tank. Set your timer or clock so you'll know exactly when the required development time is up, and immediately pour the developer into the tank. Tap the bottom of the tank sharply on the countertop several times in order to dislodge any air bubbles that might otherwise cling to the film and prevent development, and then agitate the tank for the next 30 seconds (using the method specified by the manufacturer). Agitate the tank for five seconds at the end of each 30 second interval to assure that fresh developer solution will reach the emulsion for even development of the film. Between agitation cycles, measure out the stop bath in preparation for the next step.

STEP 4: At the end of the required development time, quickly pour the developer back into the storage bottle. (Be careful not to take the tank cover off!) As soon as the developer is completely drained out, pour in the stop bath. Again, rap the tank several times on the countertop to loosen any bubbles, and then gently agitate the tank while the film soaks for at least 30 seconds.

Once film is in the stop bath, the most critical part of the film processing operation is over. Stop bath needs about 30 seconds to neutralize the alkaline developer and stop further development. It doesn't harm the film to leave it in the stop bath for longer periods of time while you're measuring the required amount of Rapid Fixer.

STEP 5: Pour the stop bath back into its storage bottle, and pour the fixer into the tank. Remember to keep the cover on the tank because the unexposed parts of the emulsion are still sensitive to light. Again, rap the tank sharply to dislodge bubbles, agitate for the first 30 seconds, then again for five seconds at the end of every 30 second interval. After the amount of time specified on the instruction sheet, pour the fixer back into the storage bottle. Don't leave film in the fixer much longer than the recommended time; too much fixing bleaches the negative — which is not at all good for astrophotos!

STEP 6: After the fixer has removed all unexposed silver halide grains, you can open the tank and expose the film to room light. But you are not finished, however, since you still need to wash away the various photo chemicals and by-products that have soaked into the soft emulsion during the previous steps. If these chemicals are not removed, they eventually will badly stain the negative.

Remove the cover, and place the tank and film under gently running water for at least 20 minutes. Be sure to check the temperature of the wash water — it must be within five degrees of your photo chemicals' temperature. You don't need much water to wash your film; just enough to refill the tank every three minutes or so is sufficient.

STEP 7: After washing, all you have to do is hang the film up to dry, right? You could, but you wouldn't be very happy. Tap water contains dissolved minerals. Large drops of water cling to the film directly after washing, and often contain enough minerals to leave a nasty round spot on your negatives after the water evaporates. To avoid water marks, use a wetting agent such as Photo-Flo 200 in a final quick rinse just before hanging the film up to dry. Wetting solution reduces the surface tension of the water to the point that most of the water runs off the film instead of clinging in drops. The film of water that does remain leaves very little residue. Hang the film up in a dust-free environment; this is important because every tiny speck of dust is glaringly apparent in star photos — they look like stars! Clip a clothespin to the bottom of the film strip to keep it straight. Letting film curl into the wall or any adjacent film leaves irreparable damage if the emulsion is scratched.

STEP 8: The film should be dry in a few hours. Cut it into five or six frame sections and store it in plastic or glycerine sleeves (envelopes) made for film storage.

The undeveloped film should have negative black and white images; on ordinary scenes, the shadows will be almost transparent (if the exposure is correct) and the darkest areas should still be easy to see through. Opaque negatives are overexposed. Your first roll should have plenty of ordinary photo shots on it; that way, if you've done something wrong you'll know the problem lies in the processing and not the pictures. If you do put a few star pictures on your first roll, you'll see why astrophotography is different than ordinary photography; a star picture has nothing but tiny little dots on it, and isn't mostly dark as ordinary scenes are.

Having developed one roll of film, you should now be curious about the fine points of processing — such as how long the chemical solutions will last. Each working solution can process only a certain amount of film before it is exhausted. Even if you don't use the solutions, after a few months they will break down (except the wetting agent and stop bath). If you continue to process film with old or exhausted solutions, you will end up with low contrast, underdeveloped negatives, or negatives that quickly fade and turn brown. Good astrophotos are hardearned while photo chemicals are cheap, so keep track of how much film each solution has processed and how long it has been on the shelf. Mark the date on which you made the solution and add a "hatch" for each roll of film the solution processed.

Developers have less processing capacity and shorter shelf life than most other photo chemicals. Manufacturers publish figures for the normal capacities of their developers, but capacity is somewhat greater for astrophotos because usually so little of the emulsion must be reduced to metallic silver when compared to normal snapshots. It's best not to take any chances, however, so follow the manufacturer's figures for capacity.

The shelf life of most developer solutions is usually specified as "one month in a tightly stoppered bottle kept at 65 to 75 degrees Fahrenheit". This figure is unnecessarily conservative; you'll find that two months is a more practical shelf life for developers.

One-Shot Developers

One solution to the problem of the limited capacity and shelf life of developers is to use the "one-shot" method. A concentrated liquid developer (such as HC-110 or Rodinal) is diluted to prepare enough working solution to develop the film. After the film is processed, the used developer is thrown out. The "one-shot" method assures fresh developer every time, but as a result of this dilution, development time is longer and contrast tends to be somewhat moderated. Many astrophotographers feel, however, that the consistent and reliable results outweigh the drawbacks.

Stop Baths

If you use a stop bath with an indicator dye (such as Kodak's Indicator Stop Bath), you will never have any trouble knowing whether it is still good or not. When this light yellow solution turns blue, the stop bath is exhausted. The working solu-

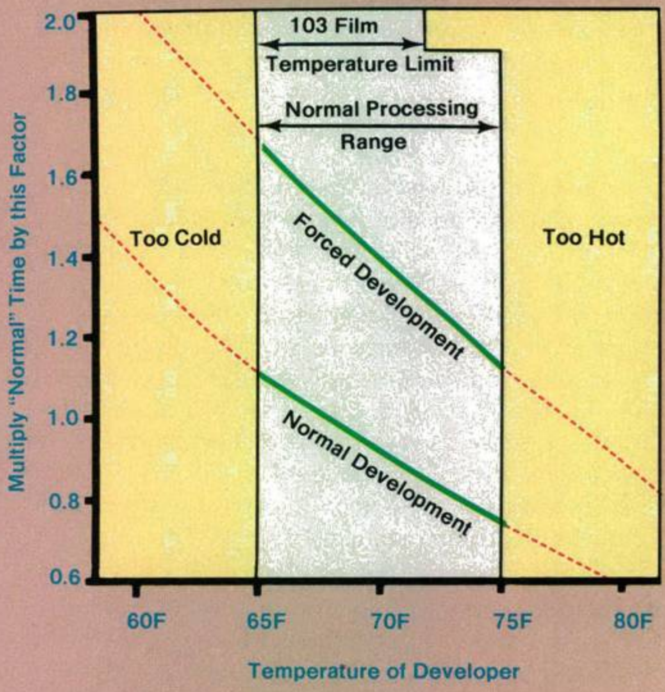
B&W Films and Developers

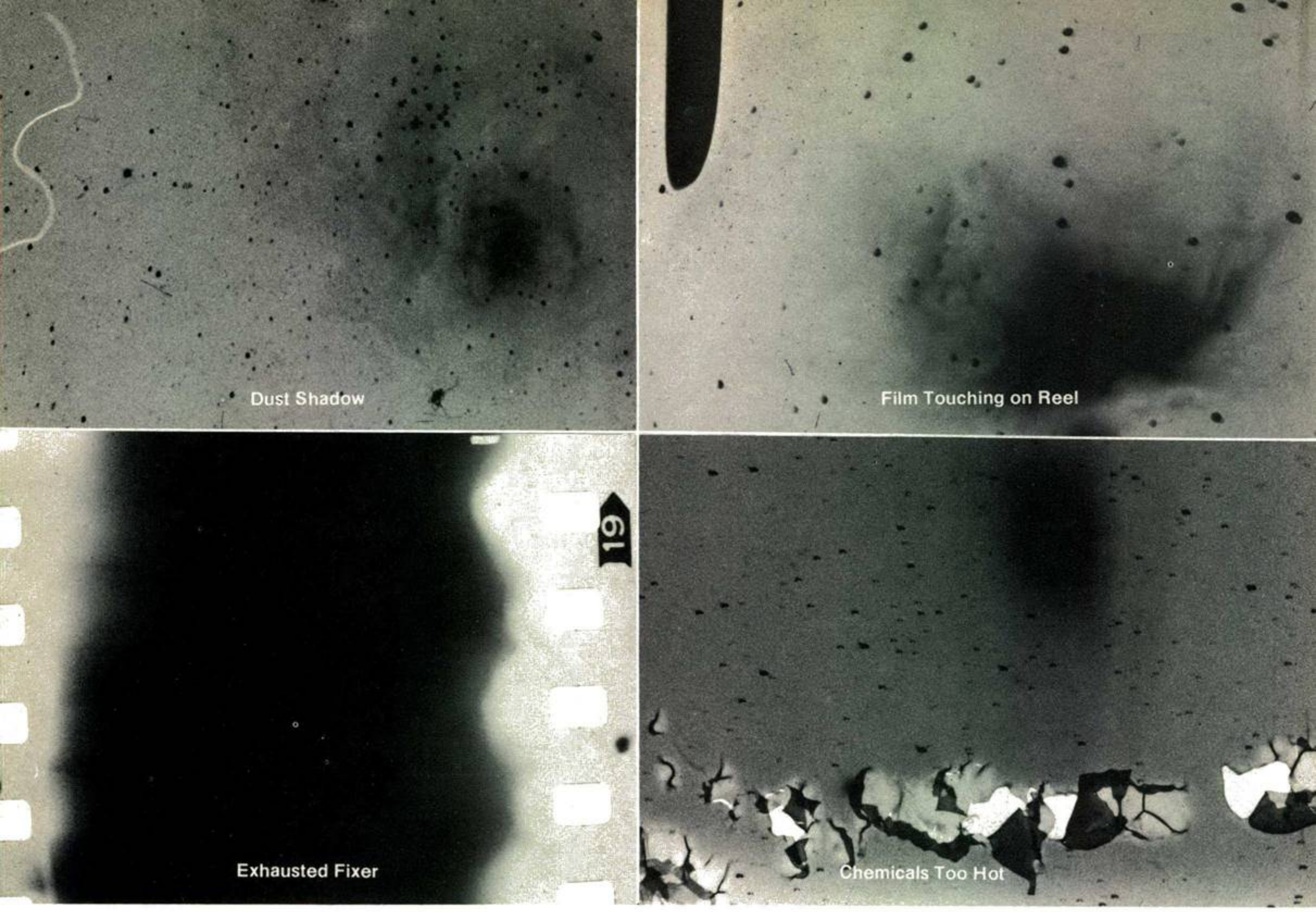
Developer	Microdol-X	HC-110A	Rodinal	D-76	D-19	Acufine	MWP-2
Characteristics	finest grain, low speed	fine grain	general purpose	general purpose	high contrast, high speed	extra high speed	maximum speed
Capacity-20 Exposure Rolls per Quart	8	10	"one-shot"	8	22	"one-shot"	22
Shelf Life	2 mo.	2 mo.	indefinite for concen trate	2 mo.	2 mo.	2 mo.	6 wks.
Film							
103aE,F,O	NR	18 (F)	NR	NR	7-1/2(F)	NR	9 (F)
Tri-X	11	3-3/4	14-1/2(1:50)	8	7	10	10
HP-4	10	3-1/2	12-1/2(1:50)	7	6	8-1/2	8-1/2
Royal-X	NR	4-1/2	NR	NR	NR	20	NR
2475	NR	8	NR	NR	7	12	NR
Plus-X	8	3	11-1/2(1:100)	6	NR	8	NR
SO-410	NR	4	15(1:100)	NR	4	NR	NR
Panatomic-X	9	2-3/4	7 (1:50)	7	5	NR	NR
High Contrast Copy	NR	2-1/2	9(1:100)	NR	NR	NR	NR

Development Time in Minutes at 68° F. (20° C.)

The table above shows which films and developers work well together for astronomical photography, and which do not produce good results. For most combinations, the normal developing time is given for processing negatives to snapshot levels of speed and contrast at 68 degrees Fahrenheit (20 degrees Centigrade). However, for a few film-developer combinations — those of astronomical interest only — an (F) indicates a "built-in" 50 percent push. To adjust the times for processing at temperatures other than 68 degrees Fahrenheit, consult the graph (right). For instance, if your developer is at 75 degrees Fahrenheit, you'll see that the normal time should be multiplied by 0.75. Thus if the normal developing time is eight minutes (as it is for Tri-X in D-76), your temperature corrected developing time would be six minutes. If you wanted to force-process Tri-X at 65 degrees Fahrenheit, you would multiply the normal time by 1.7, giving a time of 13-1/2 minutes.

Development by Time and Temperature





Dust in the camera often appears as a negative defect; cleanliness in loading the camera eliminates the problem. When loading the film reel, sometimes the film can "run off the track", preventing the developer and fixer from penetrating to the emulsion. If your fixer bath is exhausted, a yellow stain may be left on the film. The remedy is to refix in fresh fixer. Processing above recommended temperatures may soften or dislodge the emulsion. Photographs by David Hudgins.

tion lasts almost indefinitely on the shelf.

Many photographers use plain water instead of an acid stop bath. Using a water stop bath eliminates occasional pin holes that dilute acid can produce in the emulsion of some delicate films — especially 103a films. It also means you have one less chemical to fool with. The main disadvantage of using a water stop bath is that the fixer becomes exhausted more quickly than usual. If you use 103 films, the best bet is to stick to a water stop bath and limit each quart of Rapid Fixer working solution to 16 rolls of film instead of 60.

Fixer

According to Kodak, Rapid Fixer will normally process about 60 rolls of 20-exposure 35mm film per quart of working solution before it is exhausted. Astrophotos are a little different from normal snapshots as large areas of each frame are often nothing but clear emulsion. Since most of the emulsion is not exposed, and the fixer must remove more unused silver halides than in a normal shapshot, the fixer may not process as many rolls of film as stated in the manufacturer's general guidelines. A safe limit for astrophotos is 25 rolls of 20-exposure 35mm film per quart of working solution.

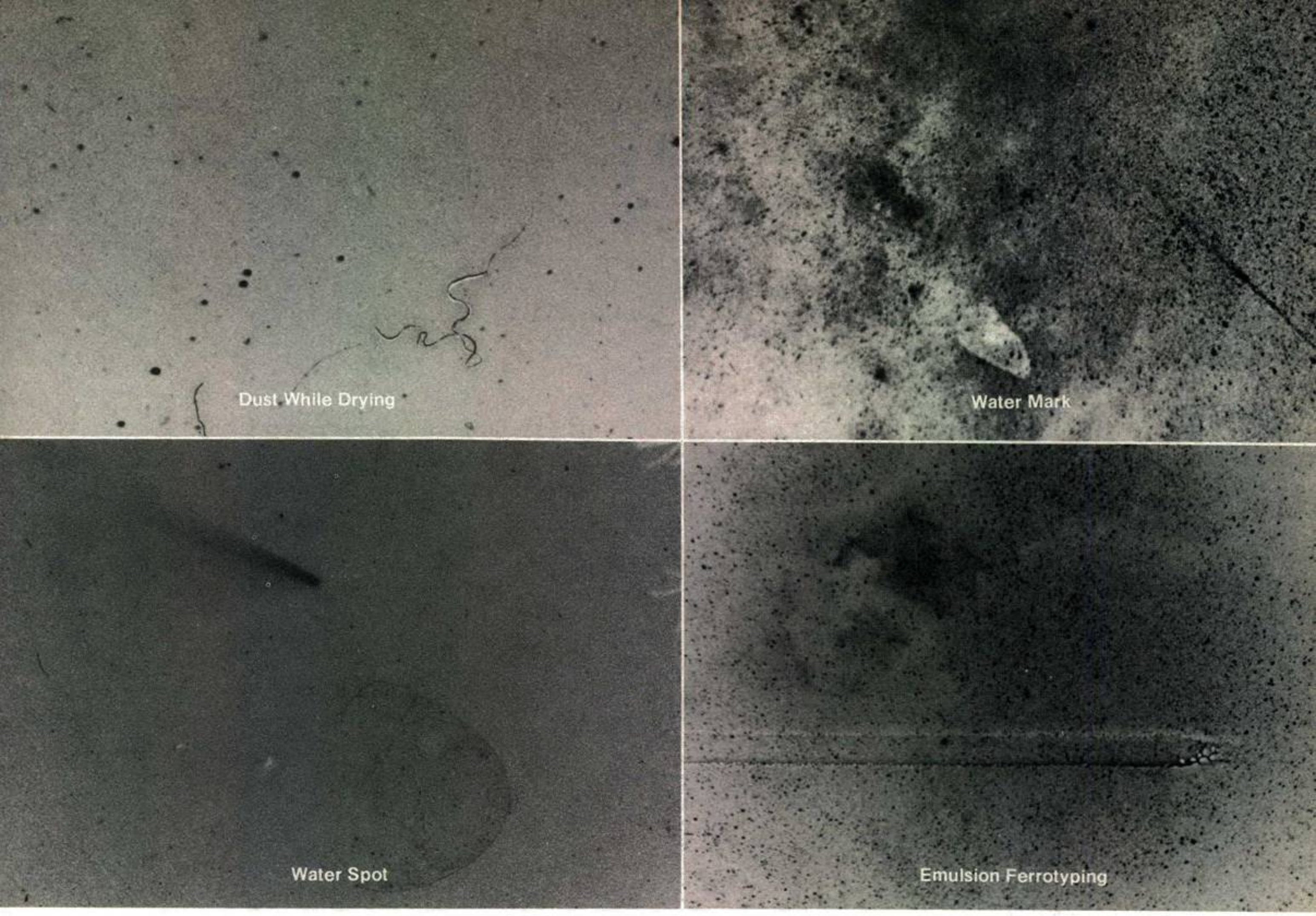
The shelf life of fixers is longer than developers. Kodak claims a life of two months for its fixers in closed bottles; many photographers find three months to be perfectly safe.

Hypo Removers

You don't have to use hypo removers, but they save a lot of time and water in processing film. These products help remove unwanted silver compounds in the emulsion after fixing; as a result, wash time can be reduced from at least 20 to 5 minutes. Don't ever skimp on washing, though. With the 103 emulsions — even with hypo removers — give at least a 10 minute wash.

Safety

None of the basic photo chemicals are dangerous if you exercise a minimum amount of caution. Many photographers routinely get the solutions on their fingers and hands with no harmful results. You should avoid prolonged contact with your skin because some people react with a rash. Naturally you wouldn't want to drink these chemicals or get them splashed in your eyes, so they should be stored out of reach of inquisitive youngsters. All the basic chemicals can be safely handled by a conscientious 12 year old, however.



Dust on the emulsion during drying will leave a permanent mark, so be sure to find a dust-free area for drying your films. Water droplets on the emulsion side of the film leave residual light spots, while water drops on the back leave a dark residue. Water marks cannot be removed, but spots sometimes come off with gentle rubbing. If the film dries while pressed against another object, it can ferrotype, leaving a permanent bump on the emulsion. Photographs by David Hudgins.

Astrophotographic Processing

We have been discussing what might be called the "normal" processing of films. Normal processing refers to a combination of developer and developing time producing negatives of everyday scenes which will produce a full tonal range on moderate contrast printing papers — from jet black, through many shades of gray, to almost pure white.

Planets, stars and nebulae *are not* in the same photographic category as conventional snapshots — grain, contrast and film speed are of much greater concern — and sacrifices of one sort or another are almost the rule rather than the exception. In order to bring out the most planetary detail or show the most stars, you will almost certainly find it worthwhile to use more powerful films, developers and processing techniques than the average photo enthusiast.

To get the best pictures, start with a film that is suited to the type of astrophotography you have in mind (see "Choosing B&W Films", ASTRONOMY, May 1976). By developing your own film you'll have a much greater choice of emulsions than you had before. Through your camera store or by mail order you can buy fine grained films (like High Contrast Copy or Kodak SO-410) for use on the planets, or one of the powerful 103a spectroscopic films for stars, nebulae and galaxies. After selecting a film, but *before* making the exposures, you should plan how that film is to be processed. Many general purpose developers (like D-76 or HC-110) give very nearly the same results, but the use of specialized developers or extended processing time can make significant differences in the images that appear on your finished negatives. With a particular film, one developer may give the finest grain possible, a second may emphasize contrast, while a third may yield the very highest film speed with relatively coarse grain.

What processing will give you the best results? That depends on your astronomical subject, equipment, and the film you will be using. Developers such as Microdol-X and HC-110 (dilution B) give the finest grain for many films, but the film speed and contrast will be a bit lower than normal. For shots of Venus and some lunar photography, sacrifice in contrast may be worth the relatively grainless enlargements that can result!

Most planetary photography benefits from developers that produce higher than normal contrast levels, emphasizing detail — the cloud belts on Jupiter, or the subtle surface detail on Mars. You should stick with a fine grained film but use a more powerful developer like D-19 or HC-110 (dilution A) — rather than Microdol-X. Rodinal is also a good choice: It can produce razor sharp definition with fine grained films such as Panatomic-X and Ilford Pan-F.

You can also raise contrast by simply increasing processing time in the "normal" developer (such as D-76 or HC-110) by 30 to 50 percent. Extended development also raises the effective film speed crucial at long focal lengths when exposure times must be short in order to minimize the effects of atmospheric turbulence and drive inaccuracies.

A particular film could be processed in several developers, depending on the results desired — but don't let this mislead you into thinking that you can mix *any* film with *any* developer. It might seem like a clever idea to use a fine grain developer such as Microdol-X with a fast but notoriously grainy film like 103aE, or the superdeveloper MWP-2 with an ultrafine grain film, but it usually won't work because the film simply isn't capable of delivering that kind of performance! Developers can't change a film's basic nature; they only reveal its full potential.

For deep sky photography, none of the common snapshot films give satisfactory results with commercial processing. You can, however, force process relatively fast films such as Tri-X or Ilford HP-4 to much higher effective speeds than their normal ASA 400 rating. The extra speed, as well as increased contrast, will accentuate faint stars and nebulae that might otherwise have been missed.

The easiest way to force process, or push, high speed films is to extend development time by about 50 percent in a general purpose developer (such as D-76 or HC-110). This usually doubles the normal film speed. Special developers such as Acufine and Diafine will increase film speed even more; for example, the speed of Tri-X can be multiplied six times in Diafine.

Force processing film to higher effective speeds has obvious potential, but you should also be prepared to pay some penalties. For the astrophotographer, the biggest drawbacks to force processing are: 1) loss of detail in the brightest areas of nebulae or globular clusters due to increased contrast; 2) reduced sharpness and increased grain size, and 3) higher fog levels of the dark sky background. Coarse grain is bad, but only your personal tastes limit how much grain is too much. Fogging of the film is another story. Fog results when powerful developers or prolonged development times cause *unexposed* silver halides to be converted to metallic silver. By forcing development too far, fog obscures additional increases in the contrast of dim stars. Forcing film beyond moderate fog levels will show fewer stars and less nebulosity than more conservative development. Remember that the practical limit to all film processing is the film's inherent potential, and it may take a little experimentation to find out just what the limit is for you and your equipment.

Special Treatment for 103a Films

Force processing will reveal a lot more faint detail using common films, but none of these common films will record dim astronomical objects as well as the 103a spectroscopic emulsions (available from Optica b/c). By far, the best way to process 103a films is to use the powerful developer MWP-2. This developer was formulated by scientists at Mount Wilson and Palomar Observatories expressly for spectroscopic films, and it effectively doubles the speed of the special emulsions. MWP-2 can also be used on films like Tri-X for substantial speed gains. (One source of MWP-2 developer is Clayton Chemical Co., 3867 Grandview Blvd., Los Angeles, Calif. 90066; a one gallon package costs $5.)

Before trying one of the 103a films, there are a few points you should be aware of. 1) Unlike conventional films, spectroscopic films must be stored in the freezer to prevent thermal fogging. If you plan to use a single roll over several consecutive nights of shooting, you can safely keep that roll in the refrigerator for a week or so without any problems. Leaving 103a films at room temperatures for more than about 24 hours will produce fogging, especially if you force process the film in MWP-2 developer. 2) 103a emulsions become very soft and fragile at high processing temperatures. A good rule is to never develop these films with solutions or wash water warmer than 72 degrees Fahrenheit (22 degrees Centigrade). 3) Don't use an acid stop bath with 103 films — use a water rinse. Acid can cause pinholing in the delicate emulsion. 4) Remember that it's especially important to use fresh fixer with the thicker 103 emulsions. Stick to the 16 rolls per quart recommendation for Rapid Fixer. 5) 103a films have a special black coating (called "rem-jet") on the back of the film base. This coating reduces the unwanted spikes and halos around bright star images which result from light scattering off the film base. The coating may dissolve in the water stop bath immediately after development, but sometimes it doesn't. Whatever remains can be *gently* wiped away, using a clean wet cotton ball soaked in developer, after fixing the film. Rinse, refix the film briefly, then wash normally. The developer may become filled with rem-jet; if it does, discard it or filter it. You don't want any rem-jet left on the film at all. Soak 103a film in a wetting solution (Photo-Flo) for a minute or so before you hang it to dry.

So that's it — from developing your first roll, to the tricks and pitfalls of forcing the very faintest celestial detail out of your films. The basics are simple and inexpensive. You can be using the powerful tools of photography to get even more beautiful and revealing photos of the incredible universe around us!

ASTRO-NEWS

Latest News From the World of Astronomy

Applications Available For Space Shuttle Crews

Affirmative action has found its place in space. NASA announced recently that it will start recruiting women and minorities, in addition to men, for the Space Shuttle program.

Thirty positions will be open — 15 for pilot candidates and 15 for mission specialists. Those chosen will undergo two years of training and evaluation at the Lyndon B. Johnson Training Center in Houston, Tex.

In order to qualify, pilot applicants must have a bachelors degree in engineering, physical science or mathematics. They must have 1,000 hours of flight time as a pilot; experience with high performance jet aircraft is highly desirable. Applicants who have had experience as test pilots will have an added advantage.

Those who are applying for posts as mission specialists need not be pilots. The educational requirements are the same except that biological science degrees are included in the education category. Prospective pilots and mission specialists must pass a NASA Class I and Class II flight physical, respectively.

The presence of women has raised some debate as to the adaptability of the Shuttle. "The Space Shuttle has been designed to accomodate women astronauts," explained a NASA spokesperson. "The waste management system is the only problem, and that has been designed for both males and females."

When in operation the Shuttle will perform Earth orbital missions for as long as 30 days, and return — landing like an airplane — to be refurbished for another flight. Pilots will control the craft during launch, orbital maneuvers and landings, and be responsible for maintaining vehicle systems.

Mission specialists will be responsible for co-ordination of overall orbiter operations in the areas of flight planning, consumables usage and other activities affecting payload operations. The specialists will be able to continue in their chosen fields of research, and to propose, develop and conduct experiments.

The Shuttle crew may consist of up to seven people — commander, pilot, mission specialist, and up to four payload specialists. The payload specialists need not be NASA employees, and will be nominated by the sponsors of the payload being flown.

Prospective applicants may have to wait to get into space, as NASA already has 31 people available as potential crew members. Twenty-eight are astronauts assigned to the Johnson Space Center, and three hold government positions in Washington, D.C.

NASA is tentatively planning about 60 flights per year by the mid-1980s. This figure is dependent on the potential users in government agencies and private industries from the United States and abroad.

Redshift Provides Clue to Quasar Distance Question

Relative redshifts of a galaxy and a quasar behind it may be the evidence needed to determine whether or not quasars are at extreme distances from Earth.

A team of astronomers, sponsored by the National Science Foundation, has studied a singular quasar designated 3C 286, using the Very Long Baseline Interferometry (VLBI) method. VLBI uses two radio telescopes that are placed a great distance from each other to look at the same object. Careful sychronization of the two scopes has the effect of one huge telescope that can read details 100,000 times smaller than if the instruments were used separately.

The astronomers were first able to study the gas cloud in front of 3C 286 with radioscopes at the National Radio Astronomy Observatory (Green Bank, W. Va.) and the National Astronomy and Ionosphere Center (Arecibo, P.R.), separated by a distance of 1,800 miles (2,892km).

According to one of the team astronomers, Arthur Wolf of the University of Pittsburgh, "The point of agreement which has arisen out of the debate over quasar distances is that the discovery of a galaxy of large redshift in front of a quasar with even larger redshift would establish the quasar at cosmological distances. The quasar must then be at least as far away as the galaxy whose distance can be clearly deduced from its redshift."

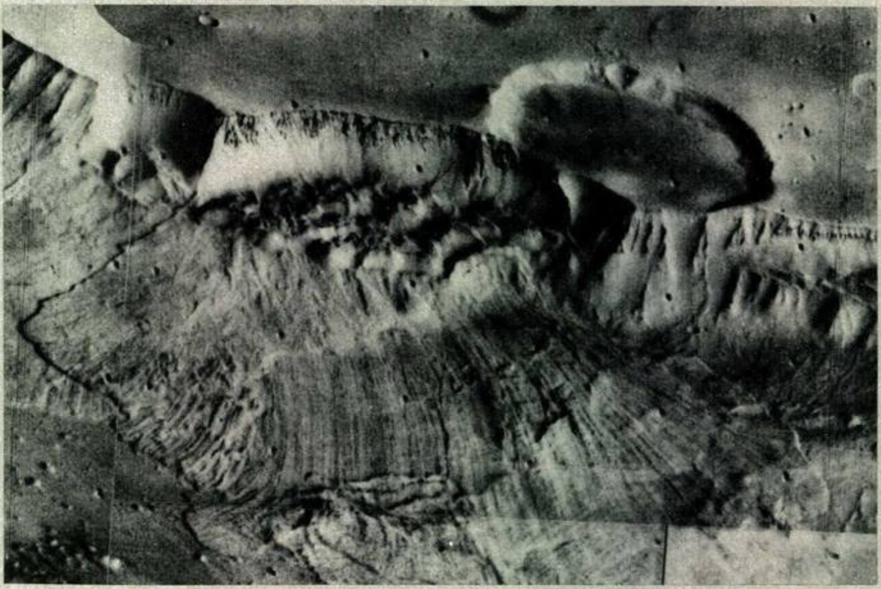
The research indicated that the cloud in front of 3C 286 was not the usual cloud that is ejected from a quasar. Further studies revealed that it resembled the hydrogen cloud seen in galaxies. The hydrogen cloud associated with the galaxy exhibited a redshift of 17 billion light-years, while the quasar behind it registered at 22 billion light-years distant.

Some astronomers question the validity of the redshift rule. At such large distances the visible light emitted by a quasar would be generated by energy greater than that of a galaxy with hundreds of billions of stars. Skeptics argue that the energy requirements would be reduced if quasars were not as far away as their redshifts indicate. The discrepancy between the 17 billion light-years of the galaxy and the 22 billion light-years of 3C 286 seems to support the great distance theory.

Viking Orbiter Continues Exploration of Mars Surface

Despite the daily media coverage about the Viking landing, many people have forgotten about the spacecraft left in orbit while the lander touched down on Mars. The fact is that the orbiter's work is continuous and not only necessary, but as scientifically exciting as the lander's work.

The orbiter will monitor and explore Mars as a whole for at least two and up to a maximum of 10 years. The landing program offers detailed looks at two places on Mars. However, Mars has turned out to be an incredibly varied planet, with many different environments. For example, there are eroded low plains where liquid water could condense, high volcanic mountains where water could boil away, polar ice fields, cratered uplands with features billions of years old, geologically young sand dunes, windy canyons, and winding channels probably carved by running water about 100 million years ago.



This series of photographs illustrates the five geological processes of Mars: cratering, lava flow, aeolian transport (windblown), landslides and water flow. These photos, taken by the Viking orbiter, help determine the context of the area the lander works in. NASA photographs.

While the lander fills in the geologic and climatic details of two sites and conducts the search for life, the 32-foot-wide orbiter circles the planet. While awaiting the Viking 2 orbiter, it is sighting other regions with three instruments: an infrared device to measure temperatures of Mars and its atmosphere; another infrared device to measure the amount of water vapor in different areas and the air pressures in regions where water vapor is detected, and a pair of cameras to scan the surface.

Whereas the lander pictures showed Martian terrain similar to what most scientists had expected, the orbiter pictures continue to be a surprise. A variety of geologic processes have been revealed. With regard to lunarlike processes, the photos reveal new details of Martian cratering. Many giant meteorites (probably from the nearby asteroid belt) have pelted Mars in the 4.6 billion years since the solar system formed. The impacts made craters (many of which are now eroded) which serve as an index of Martian erosive conditions. Among the largest surviving craters is the 1,000km Argyre basin (the eastern part is shown in photo No. 1 on the facing page). The basin rim is resolved into a zone of broken, steep hills. In the bottom left foreground are regions of gullied terrain giving the appearance of dendritic stream erosion, though this interpretation is uncertain. With its craters, gullies and clouds, this picture is an excellent introduction to the complexities of our neighboring planet.

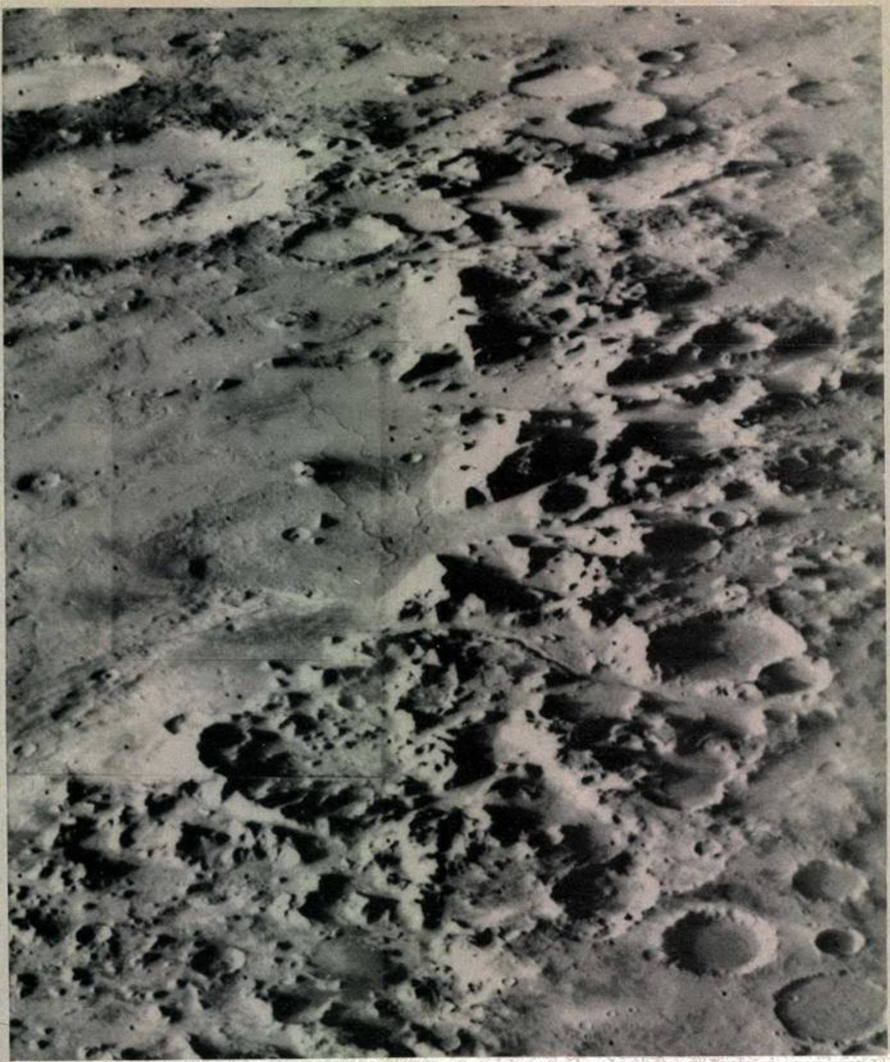
Lava flows are a second major geologic process on Mars, as revealed by various orbiter pictures such as No. 2. The lava flow follows a dry river channel alongside a cliff in the Kasei Valley. Wrinkle ridges in lunar maria are sources of many lunar lava flows; they may mark faults from which lava has extruded and accumulated. Wrinkle ridges are also common on Mars (Argyre basin interior, photo No. 1), adding to evidence that many Martian plains are made of lava layers.

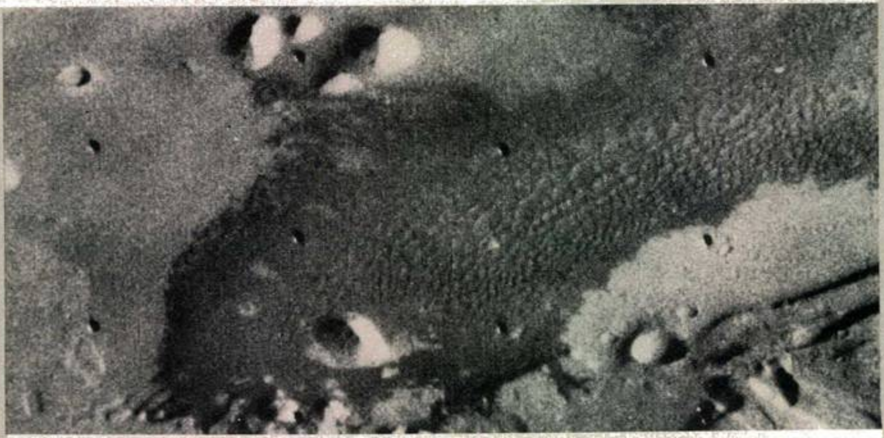
A third process is windblown, or aeolian, transport of dust, carrying off debris from some areas and depositing it in other areas in the form of dunes. While fields of small dunes appear in the lander pictures, orbiter pictures show whole areas — tens of kilometers across — covered by dunes. An example is shown in photo No. 3. The canyon floor illustrates the dark field of sand dunes, about 31 miles (50km) long and 12 miles (20km) wide. The canyon, Ganges Chasm, is a branch of Mars' great equatorial canyon system. Individual dunes are 1,600 feet (500m) across. The wind appears to have been blowing from the west (lower left), and the leading dunes to the east (upper right) are starting to climb the canyon wall.

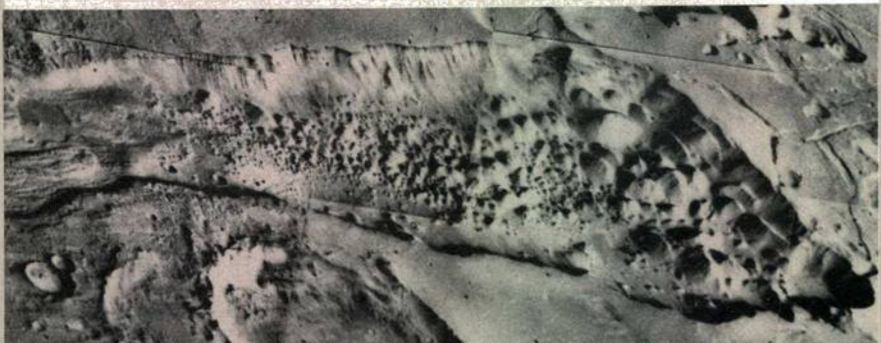
A fourth process shaping Mars is landsliding. While Mariner 9 photos only hinted at this process as a means of widening canyons, Viking orbiter photos give vivid new evidence of it. Photo No. 1 on page 56 shows a view looking south across the great Valles Marineris. On the canyon's 6,000 foot high far wall, a large crescentric mass has slipped loose and crumpled into the canyon, sending a large flow tens of kilometers across the valley floor. This flow, striated in the direction of movement, overrode an earlier similar flow to the left. A third flow of this type is seen at the foot of the north wall in the lower left foreground.

Landslides and canyon widening may be related to a fifth process, water flow. Since Mariner 9, scientists have reluctantly concluded that liquid water flowed in Martian channels at some time in the ancient past — "reluctantly" because no water source was obvious. Only traces of water are now in the Martian atmosphere. Water seems the best explanation because the

Viking *continued on page 58*







Soviet Salyut 5 Concentrates On Earth-Based Observations

After the impressive Soviet space astronomy work conducted on the Salyut 4 space station in the first half of 1975, the Russian space program has turned to terrestrial space applications for its new Salyut 5 orbital outpost. Launched in June, Salyut 5 was manned with a two-man crew sent into space in early July.

Cosmonauts Boris Volynov and Vitali Zholobov began their space mission with the task of unstowing and checking out equipment on board the 20 ton space station. Although the Soviet news agency described the flight's objectives in terms of science and applications, Western analysts learned much more from Salyut's flight path and other factors.

Salyut 5 has confirmed the suspicion of many non-Communist space specialists that the Salyut program has two distinct but parallel efforts. One type of Salyut — typified by Salyut 4 — is devoted to scientific experiments, concentrating on astronomy and biology. Another type (Salyuts 3 and 5 are examples) flies at a lower altitude and is devoted to observations of Earth, for both scientific and military purposes.

During the first three weeks of the flight, Soviet news coverage was very low-key. Experiments in space biology and engineering were described.

The experiments described in the Soviet press, however, were not enough to absorb the Russian spacemen's full time. During the Salyut 4 scientific mission, Soviet scientists released voluminous data on each day's activities. During Salyut 5, days have passed when the flight has not even been mentioned in the Soviet press.

Amateur radio listeners in Europe and America noted the simularities in radio signals between Salyut 5 and Salyut 3, two years before. However, after several weeks in orbit, the crewmen apparently began using a voice scrambler system — a step never taken on the Salyut 4 flight.

Another interesting factor was the makeup of the crew, which included no civilian researchers (as was the case on Salyut 4). Instead, the first Army officer to fly in space was acting as copilot. The commander was an Air Force colonel who had made one previous space flight in 1969.

Although the space station is described as the fifth in the program, at least seven have been launched into space in five years. This is the fourth Salyut to be boarded by a crew.

The first Salyut spent six months in orbit in 1971. During that period it was visited by two teams of space pilots. The first were unable to board the craft, and the second perished on their return to Earth after 24 days in space.

In 1972 and 1973, three more Salyuts were launched. Rocket failures and spacecraft control problems prevented crews from establishing residence in orbit.

The first successful Salyut visit was not made until mid-1974, when two Soyuz 14 cosmonauts spent 16 days inside Salyut 3 before returning successfully to Earth. A second crew launched the following month failed to link up with the Salyut, and had to abort the mission.

In 1975, two pairs of cosmonauts spent 30 and 63 days in space on Salyut 4. A third team of space pilots had also been launched, but their booster rocket failed and they came down in the snowy Altai Mountains of Siberia. They were rescued the following day and are now again in training for a future mission.

Western observers expect Salyut 5 to be home during a number of visits from cosmonauts during its one year lifetime. Early in 1977, a new Salyut will probably be launched carrying astronomical instruments similar to those on Salyuts 1 and 4. For this mission, the observational target is Earth and its atmosphere.

Viking *continued from page 56*

channels have all the characteristics of terrestrial river systems (especially catastrophic flood systems). A clue about Martian water sources is found in photo No. 4. At left is a classic pattern of flow lines in a channel, indicating water flow from right to left. But where did it come from? Tracing it to the right, we find the only source to be a box canyon full of chaotic debris probably derived from landslides. The suggestion of geologists, based on terrestrial experience, is that the pore spaces in the soil under the surface may be saturated with ice, usually frozen. It would be permafrost, as in our arctic tundra. But sometimes, perhaps due to local geothermal heat, it melts. The water that flows under the surface leaks out of canyon walls and undermines cliffs — a process called ground water sapping. The cliffs collapse, either suddenly or by slow creep. On Mars, because of the low air pressure, ice and water, evaporation may proceed quickly, once started. This may account for sudden bursts of large amounts of water, creating the raging floods that seem to have cut their way out of many collapsed areas. This does not explain all Martian channels, since some originate not in box canyons but in tributaries in featureless deserts. Their source of water, if it was water, remains unknown.

The flow process is shown dramatically in photo No. 5, where a channel complex cuts across the Chryse region. Although some scientists have suggested that winds may have created some of these features, it is probable that the major structural channels are riverbeds, especially since the region is not far from other, larger channels attributed to rivers. The flow has been diverted around numerous obstacles. Wrinkle ridges attest that the background plain may consist of lava sheets, probably covered by dust layers. Craters often serve as obstacles to the water flow.

All these processes — cratering, lava flow, aeolian transport, landslides and water flow — made dramatic contributions to the Martian landscape. Planetary scientist Dr. Carl Sagan emphasized in the first press conference on the July 20 lander photographs, "Mars is marvelously heterogeneous." Viking project scientist Gerald Soffen added, regarding the lander, "We want to go over that horizon. We wish we had dozens of Vikings."

The orbiter is the best alternative. It goes over and over the horizon, charting the range of environments that makes up Mars. Some combination of the processes it has revealed must have shaped the first Martian landscape revealed to human eyes.

This report was filed by ASTRONOMY magazine's Viking correspondent, William K. Hartmann.

New Position With ASTRONOMY

ILLUSTRATION EDITOR

We are accepting resumés and applications for the new position of Illustration Editor on the editorial staff of ASTRONOMY. The following skills are required:

- **Thorough knowledge of theoretical and amateur astronomy.**
- **Knowledge and experience with color, 4/C process and B&W lithographic production techniques.**
- **Ability to specify caption and body copy lengths and create rough copy for captions.**
- **Ability to expand the number of contributing artists to ASTRONOMY and help them develop their talents in terms of the magazine's needs.**
- **Ability to choose, specify and/or assign photographs, diagrams, charts, tables, maps, paintings and artwork to illustrate articles in ASTRONOMY as well as coordinate and implement complete issue layout.**
- **Ability to communicate effectively with contributing artists and authors both orally and in writing.**
- **Ability to smoothly coordinate illustration assignment/selection with issue production schedules.**

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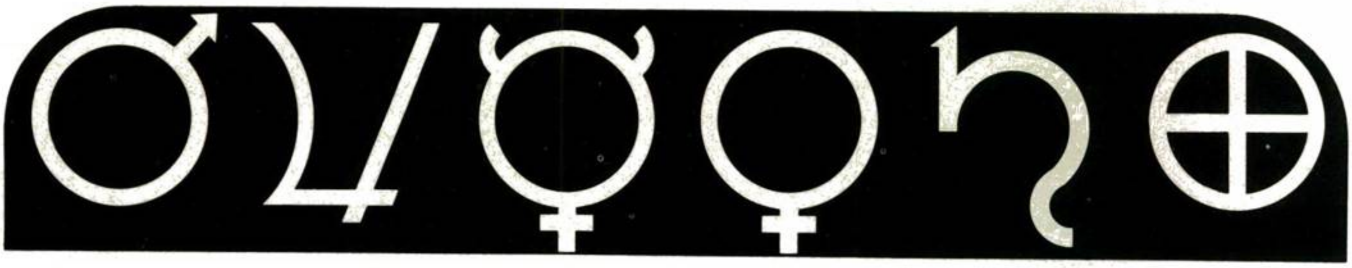
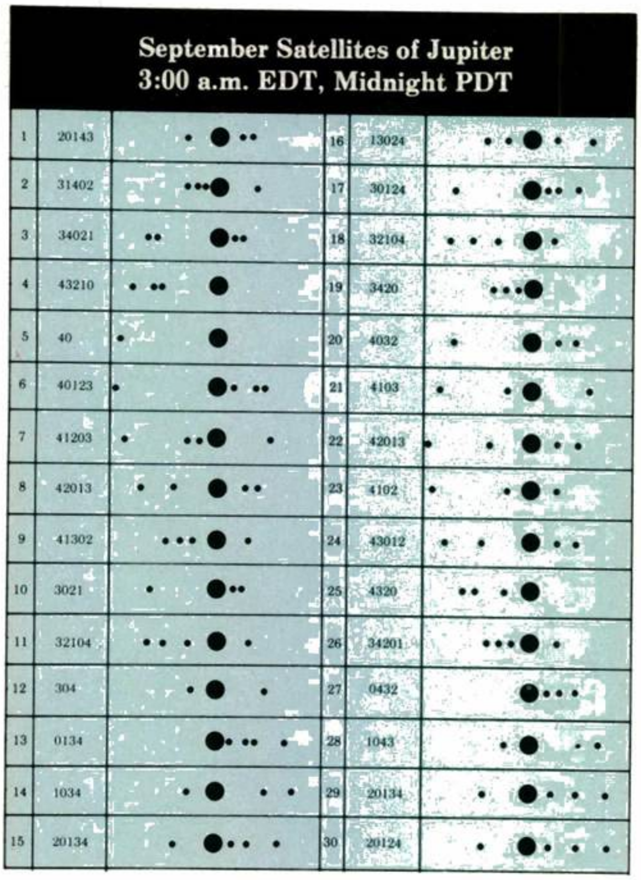


Planets Rise As Autumn Arrives



September Satellites of Jupiter
3:00 a.m. EDT, Midnight PDT

1	20143
2	31402
3	34021
4	43210
5	40
6	40123
7	41203
8	42013
9	41302
10	3021
11	32104
12	304
13	0134
14	1034
15	20134
16	13024
17	30124
18	32104
19	3420
20	4032
21	4103
22	42013
23	4102
24	43012
25	4320
26	34201
27	0432
28	1043
29	20134
30	20124

The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about 3 a.m. (EDT) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1=Io; 2=Europa; 3=Ganymede; 4=Callisto, and 0= Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.

After a summer almost completely lacking in suitable opportunities for planetary observing, conditions start to improve as autumn begins. September skies feature the two brightest planets, Venus and Jupiter, growing slowly more luminous as the month progresses. An added attraction this month is the annual appearance of the harvest moon on the eighth, heralding the approach of the autumnal equinox. The cooler and clearer nights of fall may attract those stargazers who stayed inside with their air conditioner all summer.

Mercury

During the early part of September, Mercury — located between Earth and the sun — will be difficult to observe. But by the end of the month, the planet should be visible low in the east shortly before sunrise. Its magnitude will decrease from +.8 to +1.3 during the month.

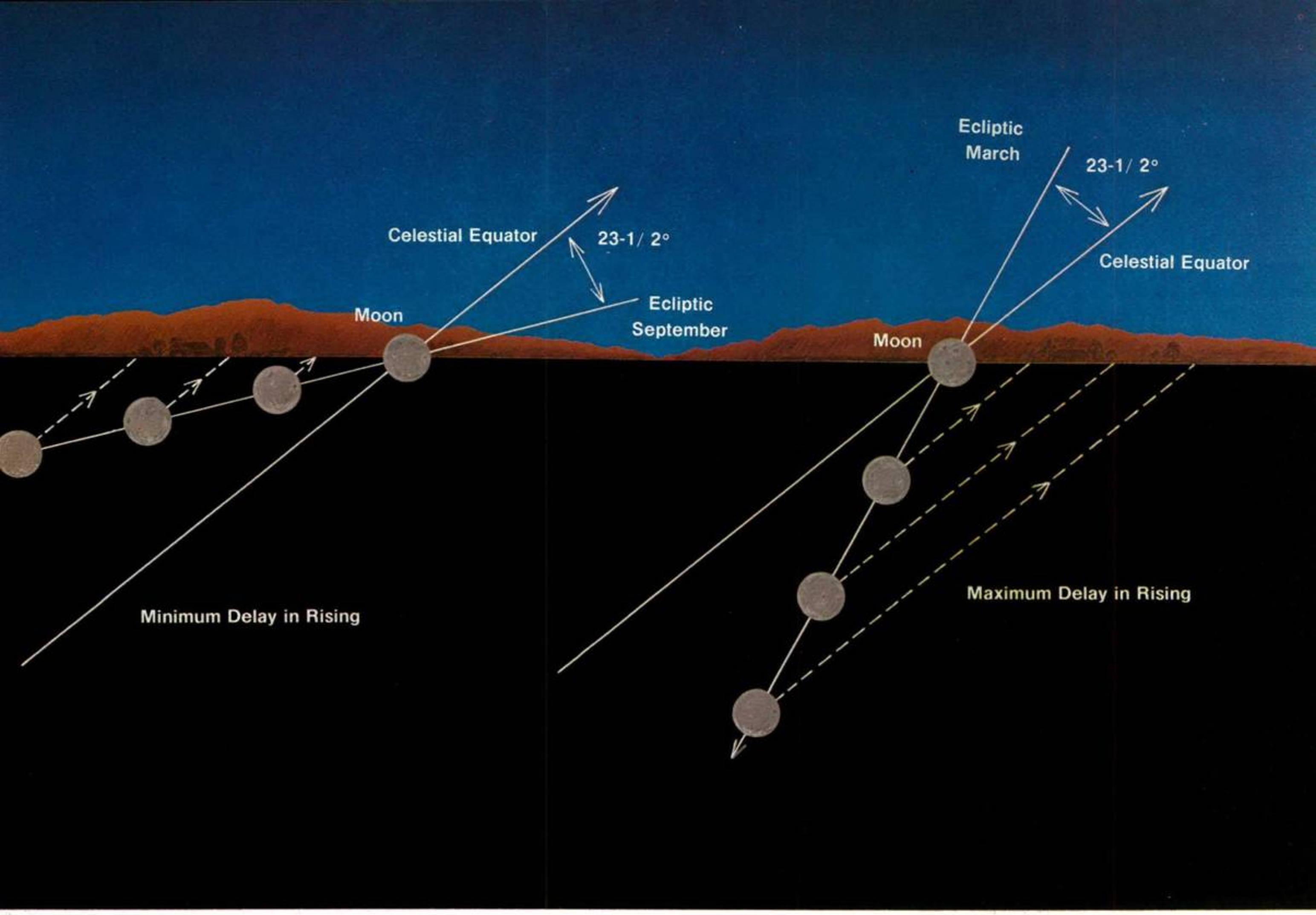
Venus

Venus is in a poor position for observation but will be getting better as the month progresses. As an evening star, it can be viewed at a magnitude of -3.3, about nine degrees above the western horizon at sunset; it sets within an hour.

Mars

The currently popular subject of the Viking missions will be barely visible in the evening sky toward the end of the month. However, a little effort may prove rewarding. On the evening of the 10th, Mars will be in conjunction with Venus, passing .4 degrees south. Its magnitude will be +1.9 during the entire month.

Top: Downtown San Diego sets the scene for this city style moonrise. This one second exposure was taken on Kodachrome II film at f/6.3 using a 400mm telephoto lens. Photograph by Martin Anderson. Bottom left: This late March aurora was photographed using High Speed Ektachrome through a 50mm f/1.8 lens for a 30 second exposure. Photograph by Brian Kutscher. Bottom right: The July 7 pre-occultation of the double star Beta Scorpii is shown in this one second exposure on Fuji R-100 film through a Celestron 8 using 40mm eyepiece projection. Photograph by Hal Jandorf.



The angles involved make the difference in the timing of moonrise between the autumnal and vernal equinoxes. In September, the moon's daily path is nearly parallel to the horizon. Because of this, the moon will rise approximately 10 minutes later each night with the time increasing in proportion to the angle involved. In March, the moon's path makes the greatest angle with the horizon; thus the time between each successive moonrise is more than the usual 51 minutes. Artwork by Mark Paternostro.

Jupiter

The largest member of the solar system is well placed for viewing this month. Located in the constellation Taurus and rising about three hours after sunset, its magnitude increases from -2.1 to -2.3. The planet will progress eastward in the early part of the month, will be stationary on the 19th, and will then begin to retrograde, moving westward among the stars shortly thereafter.

Saturn

For those of you who are predawn risers, the early morning hours feature Saturn in the constellation Cancer. The ringed planet will be rising three hours before the sun at a magnitude of +.6.

Uranus, Neptune

Uranus is in Virgo, as it has been for most of 1976, and should be visible for three hours after sunset. On the 25th, the planet will pass within .3 degrees north of the two day old moon.

Neptune is pretty far south of Ophiuchus on the ecliptic, making it difficult to observe. On the 28th, it will be two degrees south of the moon, and have a dim magnitude of +7.7

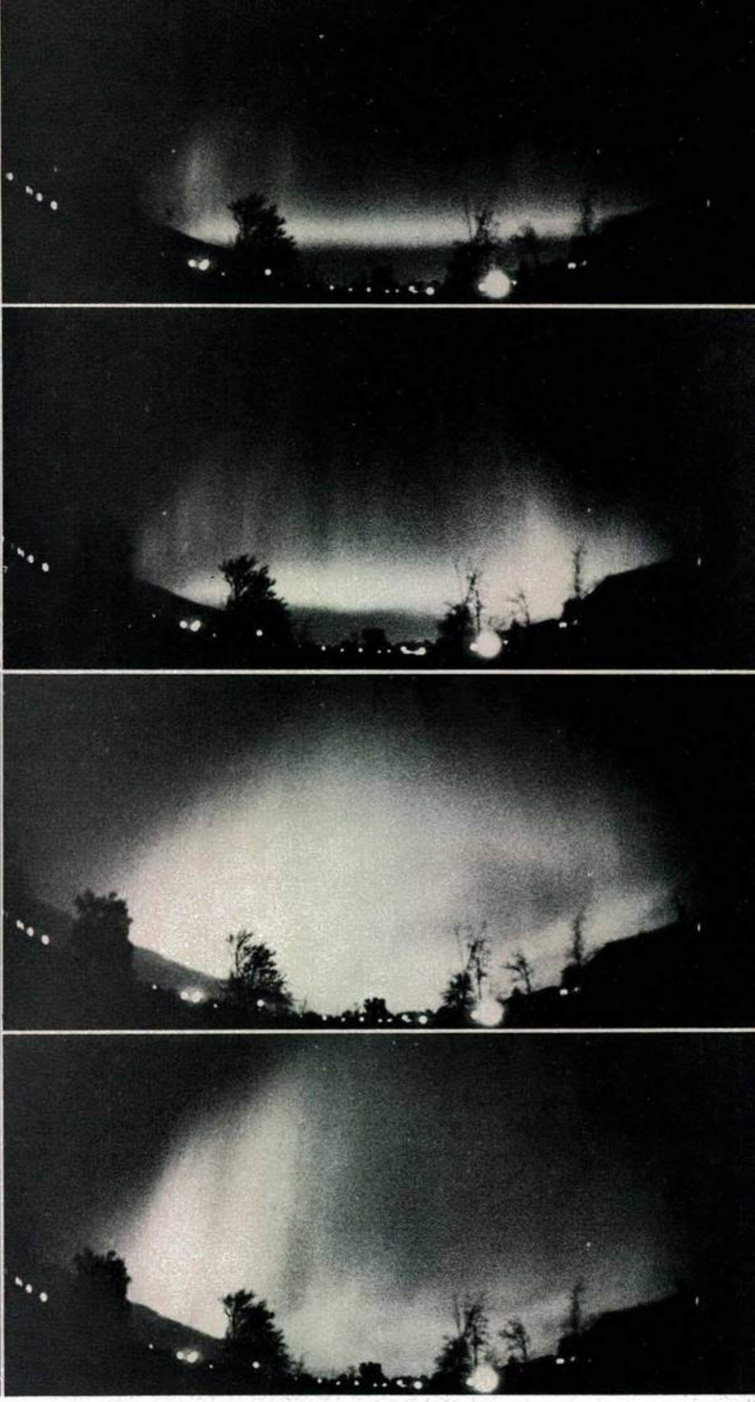
Harvest Moon

When the harvest moon is mentioned, two things usually come to mind: the song and the tradition of harvesting crops into the evening hours. But did

Satellite Shadows on Jupiter

Date	Satellite	Transit Begins (EDT	Transit Ends (EDT)
Sept. 4	1	4:32 a.m.	6:40 a.m.
	2	4:36 a.m.	7:10 a.m.
11	1	6:26 a.m.	8:33 a.m.
	2	7:13 a.m.	9:47 a.m.
13	1	12:54 a.m.	3:02 a.m.
20	1	2:48 a.m.	4:55 a.m.
21-22	2	11:10 p.m.	1:43 a.m.
22-23	1	11:44 p.m.	1:44 a.m.
23-24	3	10:20 p.m.	12:29 a.m.
24-25	1	10:13 p.m.	12:21 a.m.
25	2	12:28 a.m.	3:02 a.m.
27	1	4:41 a.m.	6:49 a.m.
28-29	1	11:10 p.m.	1:18 a.m.
29	2	1:47 a.m.	4:21 a.m.

1 = Io
2 = Europa
3 = Ganymede
4 = Callisto



Left, top: Comet d'Arrest is pictured here on July 19, 1976 in the early approach of its periodic 6.2 year orbit. The 15 minute exposure was taken with an eight inch reflector at f/5 on 103aE film. Photograph by L.F. Yuill. Left, bottom: Comet West is shown here breaking up into three parts. This photo was taken on May 23, 1976 through a Celestron 8. The 11 minute exposure on 103aE film was made at f/5. Photograph by Steve Reed. Right: This is a series of fish-eye photos of a 15 minute aurora which took place on May 2, 1976 around 10:30 p.m. CDT in Oskaloosa, Iowa. Exposure time was 15 seconds at f/5.6 on Eastman Recording film 2475 developed in DK-50 for nine minutes. Photograph by John R. Sybenga.

you ever wonder why the harvest moon seems to rise just a little bit later each night?

When the sun is at autumnal equinox, the ecliptic is below the celestial equator — thus making a small angle with the horizon (see diagram). As the moon travels its 13 degrees per day, its daily motion is along lines parallel to the ecliptic. Due to Earth's motion, the length of this path is much less than 13 degrees, so the moon appears to rise earlier than the usual 51 minute delay. This year the harvest moon is on the 8th of the month.

In March, the situation is reversed. The timing and angle of the vernal equinox makes a delay of longer than 51 minutes.

Autumn Begins

The sun is continuing in its yearly path, causing summer to fade. The fall season officially begins when the sun crosses the equator (into the constellation Libra) at 4:48 p.m. EDT on the 22nd.

During September, stargazers must bid farewell to the summer skies. But they can look forward to observing two of the solar system's brightest planets. The evening skies of autumn will feature Jupiter reaching opposition in November and Venus which will be gradually increasing in magnitude throughout the fall months.

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continued from page 27

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FOR SALE — 12-1/2" f/8.9 mirror. Finished by Cave, and coated by Pancro. Price: $150.00 firm; includes shipping. Write Peter J. Kron, 809 Cardinal Creek Blvd., Norman, OK 73069.

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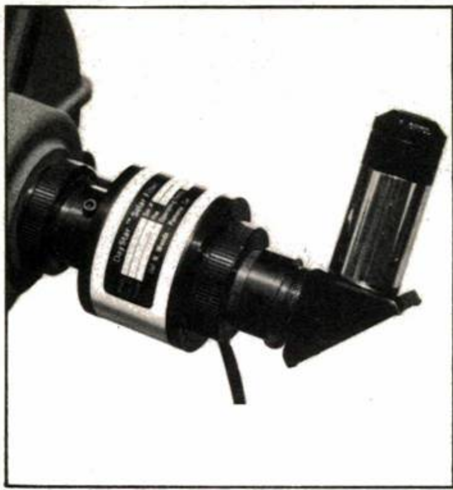
FOR SALE OR TRADE — RFT 4-1/4" coated objective with 68° Erfle (4° field, 17x, 6mm E.P.). Price: $99.00, or trade for 12-1/2" f/4 mirror. Write John S. Goulet, P.O. Box 6028, Arlington, VA 22206.



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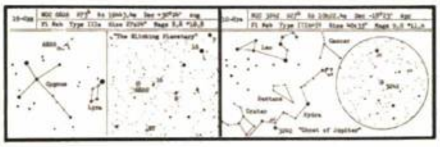

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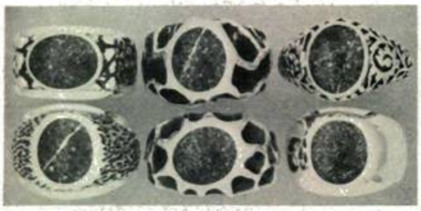

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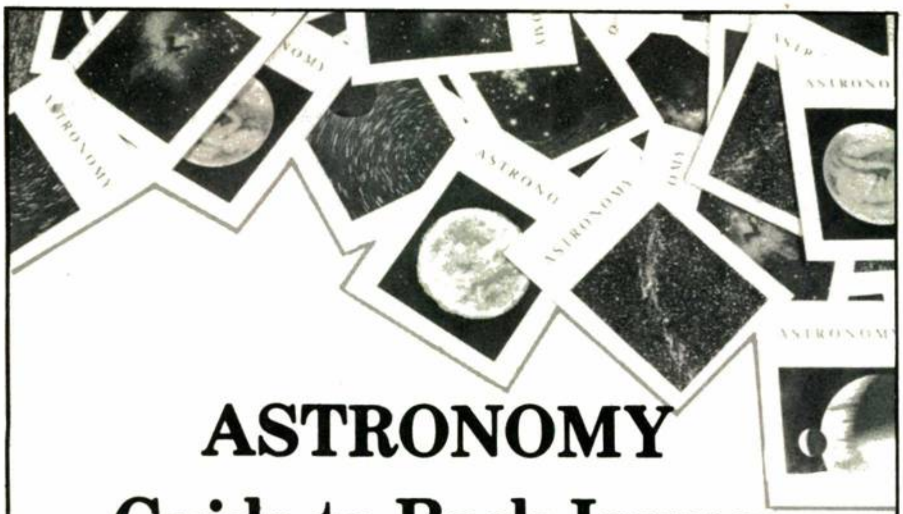

ASTRONOMY

Guide to Back Issues

Reader interest in back issues of ASTRONOMY magazine is higher than ever. As a result, our stock of back issues is swiftly dwindling. Below is a guide to ASTRONOMY back issues that are still available. For your convenience it is updated monthly; issues not listed are depleted. **The July 1976 History of American Astronomy issue is specially priced at $3.50 per copy plus postage.**

When ordering, please clearly state quantity, volume, number, month and year for each issue (first issue was August 1973), and include payment with your request. If issues ordered are no longer available, unless you instruct us to forward a refund or substitute issues, we will automatically extend your subscription appropriately.

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Vol. 2, No. 9 - September 1974	**Short Supply**	**Vol. 4, No. 6 - June 1976**	**Available**
Vol. 2, No. 10 - October 1974	**Short Supply**	**Vol. 4, No. 8 - August 1976**	**Available**
Vol. 2, No. 11 - November 1974	**Short Supply**	**Vol. 4, No. 9 - September**	**Available**
Vol. 3, No. 1 - January 1975	**Short Supply**	**Vol. 4, No. 10 - October**	***NYP**
Vol. 3, No. 5 - May 1975	**Available**	**Vol. 4, No. 11 - November**	***NYP**
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WANTED — December 1974 issue of ASTRONOMY in good condition. Will pay $12.00 plus postage. Contact Ed Ashton, 303 47th St., #H-8, San Diego, CA 92102. Phone (714) 263-9427.

WANTED — Back issues of ASTRONOMY: September 1973 through February 1974; April, May, August 1974. Will pay $20.00 plus postage. Write Marty Bergoffen, 3 Carol Pl., Brookhaven, NY 11719.

WANTED — Burnham's "Celestial Handbook" (all sections after the constellation Leo). Write Robert Bleiweiss, 3975-B Sedgwick Ave., Apt. 7C, Bronx, NY 10463.

WANTED — Observing site in Chicago/western suburb (Carol Stream, Wheaton, etc.) for 20 year old undergraduate physics major. Also suggestions on how to get the most out of an RV-6 Dynascope. Contact Richard P. Cebula, OS165 Valley Rd., Lombard, IL 60148. Phone (312) 627-0095.

WANTED — Back issues of ASTRONOMY: August 1973 through January 1975. Will pay $35.00 for set in good condition; more if necessary. Write T. Ray Davis, P.O. Box 23, Elbert, CO 80106.

WANTED — #1602E Tasco electric clock drive for Tasco telescope. Reasonable price. Write Steven Feinsmith, 748 Sherwood St., North Woodmere, NY 11581.

WANTED — Persons interested in amateur radio astronomy to join recently organized worldwide amateur radio astronomy club. Free newsletter. Send SASE to Todd Ferson, 4900 E. Hillcrest Dr., Des Moines, IA 50317.

WANTED — Camera for astrophotography for $100.00 or less. Send description, price to Roger Goodman, Rt. 2, Box 118, Goff, KS 66428. Phone (913) 866-4166.

WANTED — Persons interested in amateur astronomy club in Nashville area. Also correspondence with other astronomy clubs. Contact John Graves, 1712 S. Hamilton Rd., Nashville, TN 37218. Phone (615) 254-1852.

WANTED — Correspondence with advanced amateur astronomers/astrophotographers (preferably in Lehigh Valley area). Wish to learn advanced 35mm techniques. Currently own 12-1/2" f/7, 10" f/5, 4-1/2" f/9 with Polaroid ED-10 setup. Contact Joseph M. Kroboth, 3179 Parkview Dr., Whitehall, PA 18052. Phone (215) 264-9236.

WANTED — Persons interested in relativistic interstellar propulsion systems to join astronomy/science fiction club investigating travel to nearest stars in foreseeable future. Send SASE for membership information to John Hewitt, c/o American Tentacle Society, P.O. Box 9171, Berkeley, CA 94709.

WANTED — High quality orthoscopic eyepiece (5mm or 6mm f.l.) at reasonable cost. Send description and price to John Howard, 6032 Corbin Ave., Tarzana, CA 91356.

WANTED — August 1974 issue of ASTRONOMY. Must be in fair condition. Send price only. Also addresses of science fiction magazines. Write Norman Kolb, R.R. #1, Benson, IL 61516.

WANTED — Back issues of ASTRONOMY: August 1973 through January 1974; April 1974. Must be in very good condition. Will pay up to $20.00 for all 7 if in near-perfect condition. Contact Robert Hall, 72 Pine St., North Massapequa, NY 11758. Phone (516) 798-3957.

WANTED — Correspondence with persons (ages 13-15, preferably female) interested in astronomy and Messier objects. Write Jeff Leach, 1403 E. Salisbury St., Asheboro, NC 27203.

WANTED — Correspondence with persons qualified to give scientific theoretical analysis/explanation of UFO phenomena as physical reality (i.e.: gravity, light, electromagnetism, etc.). Not interested in psychic interpretations. Write Ralph Lillie, Box 364, Shaw Island, WA 98286.

WANTED — Interested teenage amateur astronomers to join astronomy club in the Rochester, NY area (SAROS Astronomy Club — the Junior Astronomy Section of the Rochester Academy of Science). For information, contact Kevin Lyons, 27 Westchester Ave., Rochester, NY 14609. Phone (716) 288-5185.

WANTED — Persons (ages 9-14) to join combined astronomy, rocket, model section club. For details, contact Joe McDade, 3812 Brookview Rd., Philadelphia, PA 19154. Phone (215) 637-7041.

WANTED — Complete instructions for building homemade 6" to 10" reflector. Mirror not necessary; just materials, cost, paper. Also plans for building backyard observatory. Write Tom McKinney, Rt. 2 (44 Deer Trail), Prescott, AZ 86301.

WANTED — 2.4" or 3" refractor with mount, tripod, etc. Reasonably priced. Send full details to Bill Mahan, P.O. Box 1151, Alamosa, CO 81101.

WANTED — Correspondence with persons (ages 12-16) interested in astronomy, science fiction and/or "Star Trek". Write Joy Remuzzi, 5 Robin Lane, Plainview, NY 11803.

WANTED — Field investigator for international UFO organization desires reports, leads, etc. from experienced, serious sky observers. Include as much detail as possible: date, time, location, circumstances of sighting, etc. Write Richard M. Rendler, 3660 S. Lowell, Apt. 103, Denver, CO 80236.

WANTED — Clock drive for Edmund medium duty mount (5/8" shaft, 1" housing). Must be in good condition. Write John D. Rompalo, 19 W. White St., Summit Hill, PA 18250.

WANTED — 4" lens mounting flange (4.000 x 24). Write P. Sigorelli, P.O. Box 6068, Colorado Springs, CO 80934.

WANTED — Correspondence with persons interested in ESP, hypnotism, transcendental meditation (especially in Indianapolis area). Write Paul Wilson, 4432 N. Irwin, Indianapolis, IN 46226.

POSITION WANTED — At planetarium or observatory. Have B.S. (not in astronomy). No previous experience, but very eager to learn. Write Doris Rodriguez, P.O. Box 107, Lenox Hill Station, New York, NY 10021.

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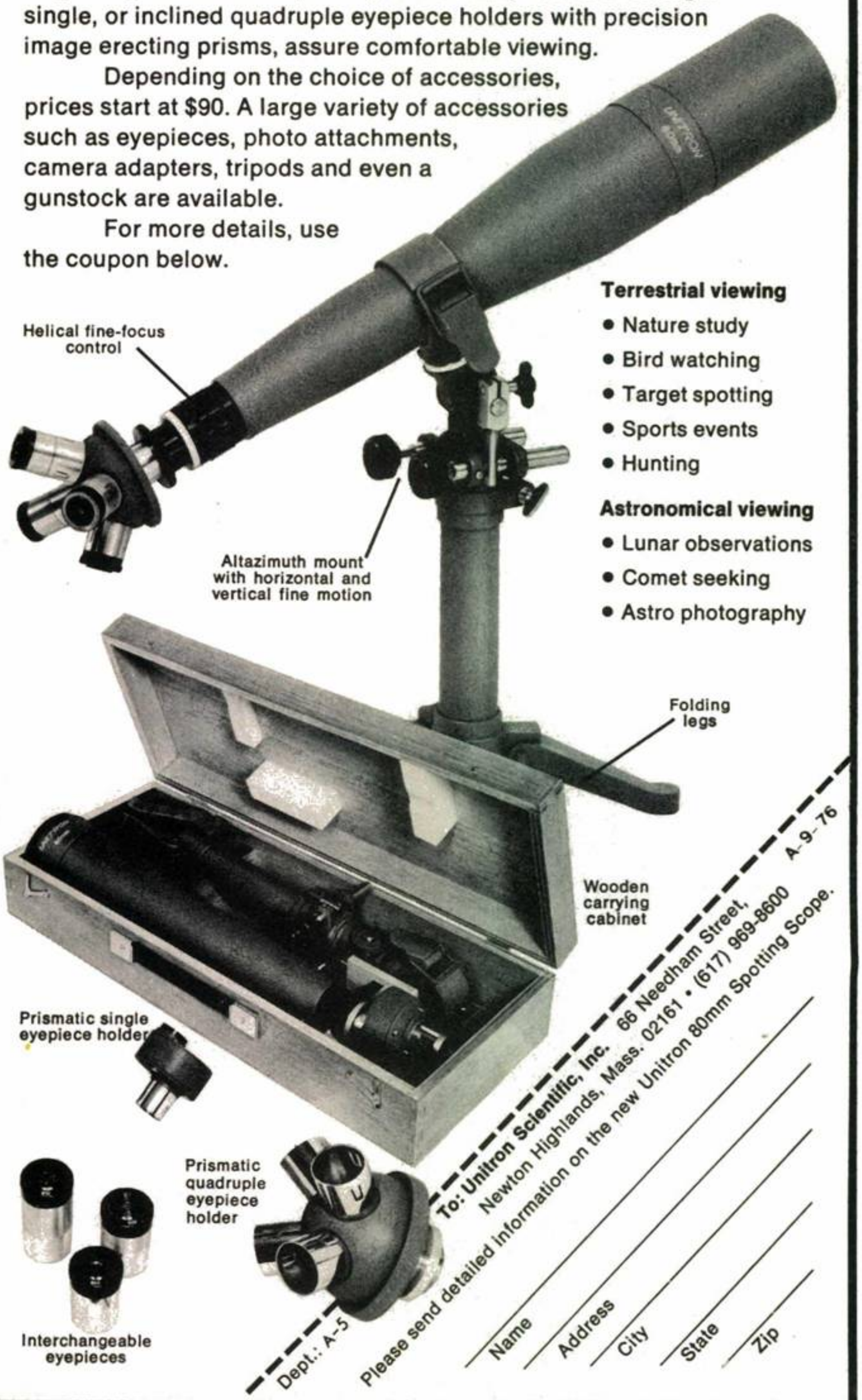
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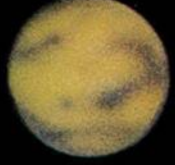
Planet Finder

Ⓒ Ceres

Sept.	1	15
R.A.	9^h37^m	10^h02^m
Dec.	+20°43'	+19°01'
Mag.	+8.8	+8.7



Ⓐ Mercury

Sept.	1
R.A.	12^h15^m
Dec.	-5°13'
Mag.	+0.7

Ⓑ Mercury

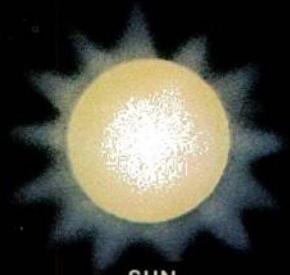
Sept.	15
R.A.	12^h12^m
Dec.	-5°43'
Mag.	+1.9

Ⓜ Mars

Sept.	1	15
R.A.	12^h21^m	12^h55^m
Dec.	-1°42'	-5°25'
Mag.	+1.9	+1.9

Ⓝ Neptune

Sept.	15
R.A.	16^h40^m
Dec.	-20°39'
Mag.	+7.7



SUN

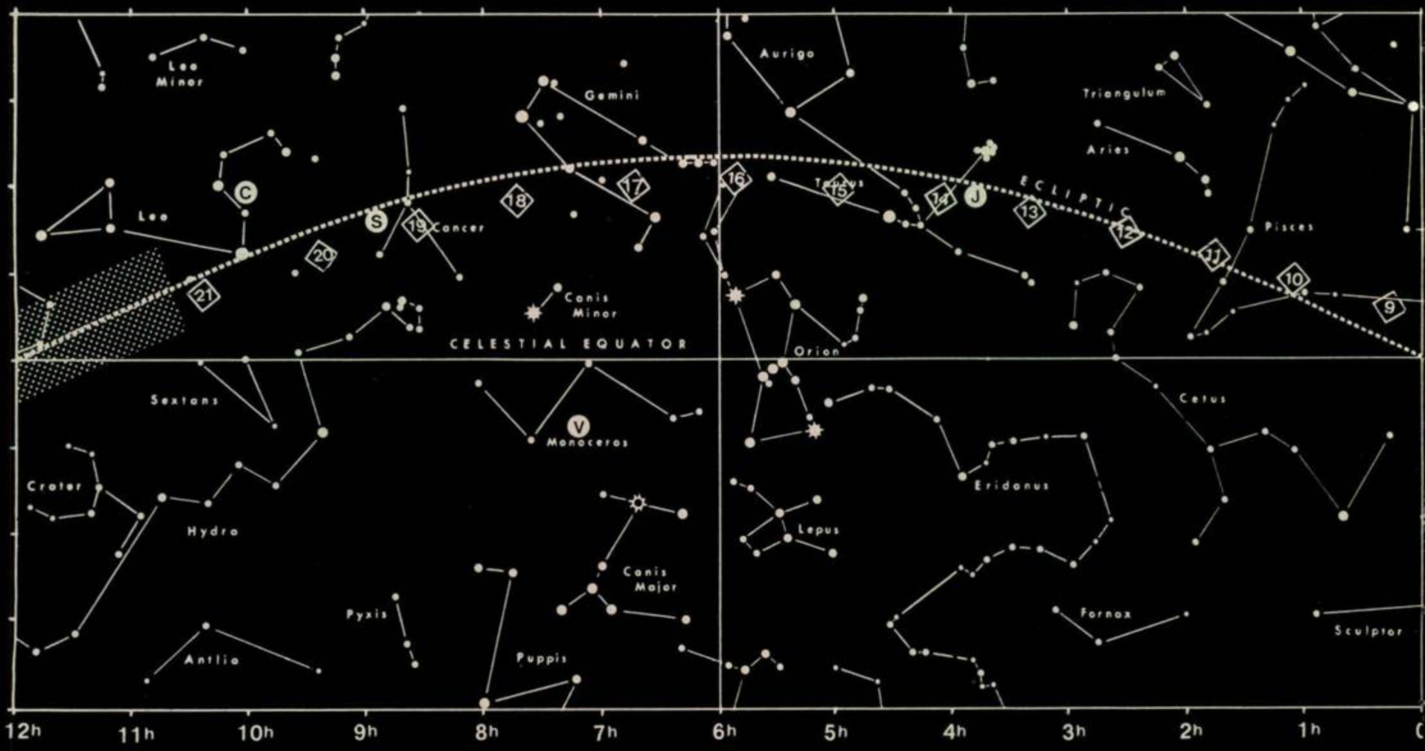
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Sept.	1	15
R.A.	8^h53^m	9^h00^m
Dec.	+18°02'	+17°37'
Mag.	+0.6	+0.6

Ⓤ Uranus

Sept.	15
R.A.	14^h10^m
Dec.	-12°43'
Mag.	+5.7

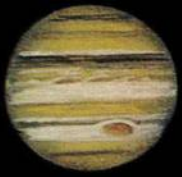

Leo Minor
Gemini
Aurigo
Triangulum
Aries
C
Leo
S
19 Cancer
18
17
16
Taurus
15
14
J
13
ECLIPTIC
12
11
10
9
Pisces
20
21
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
V
Monoceros
Cetus
Crater
Hydra
Eridanus
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

September 1976

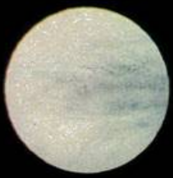
Ⓥ **Vesta**

Sept.	1	15
R.A.	6h37m	6h57m
Dec.	+20°30'	+20°18'
Mag.	+8.6	+8.4



Ⓙ **Jupiter**

Sept.	1	15
R.A.	3h55m	3h57m
Dec.	+19°15'	+19°19'
Mag.	-2.1	-2.1



Ⓨ **Venus**

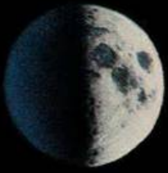
Sept.	1
R.A.	12h02m
Dec.	+0°54'
Mag.	-3.3

Ⓩ **Venus**

Sept.	15
R.A.	13h05m
Dec.	-6°15'
Mag.	-3.3

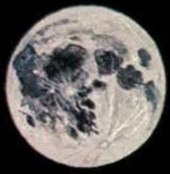
Ⓟ **Pluto**

Sept.	15
R.A.	13h04m
Dec.	+10°55'
Mag.	+14



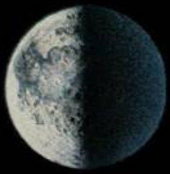
First Quarter

September 30



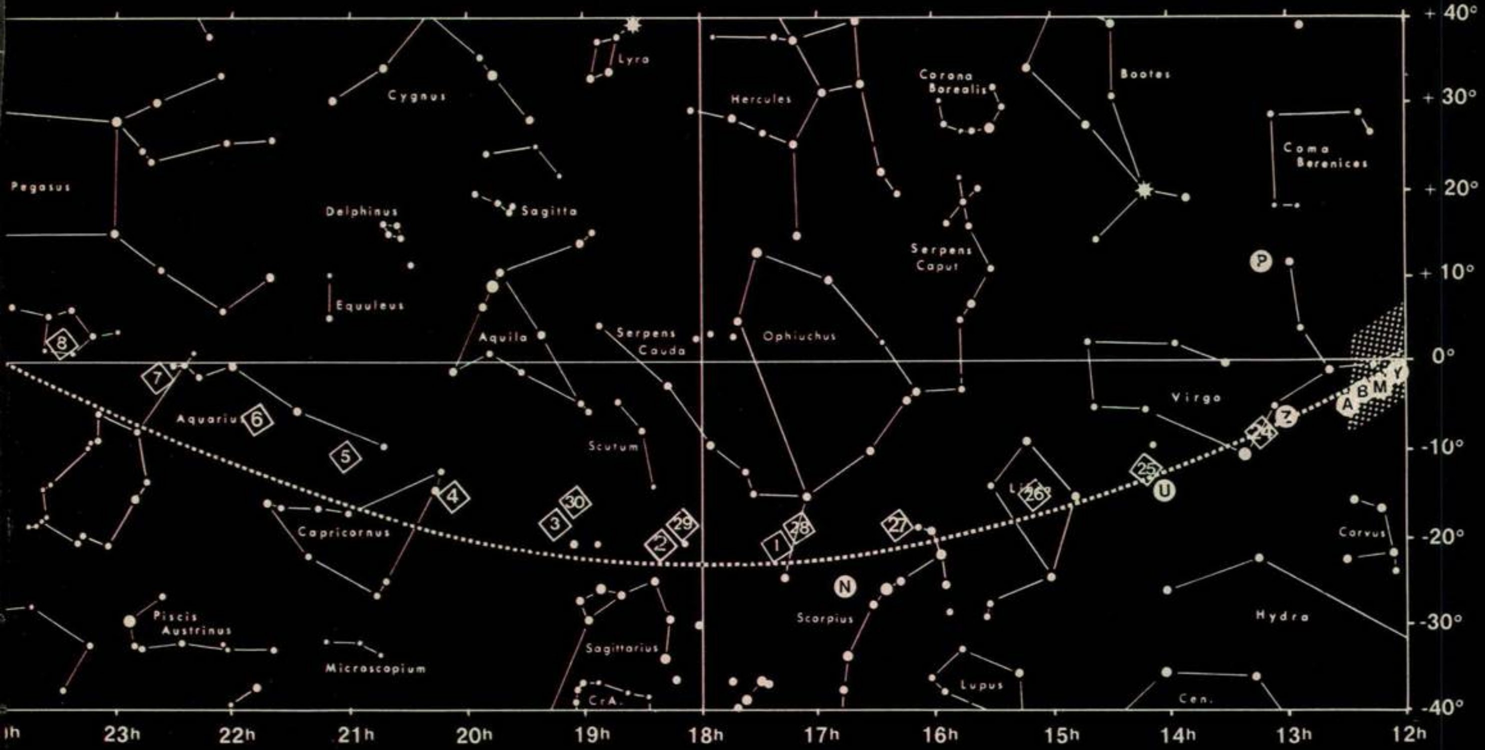
Full Moon

September 7



Last Quarter

September 15



+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
h
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Pegasus
Delphinus
Sagitta
Equuleus
Serpens Caput
Ophiuchus
Aquila
Serpens Cauda
Virgo
Aquarius
Scutum
Capricornus
Libra
Corvus
Scorpius
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA.
Cen.
P
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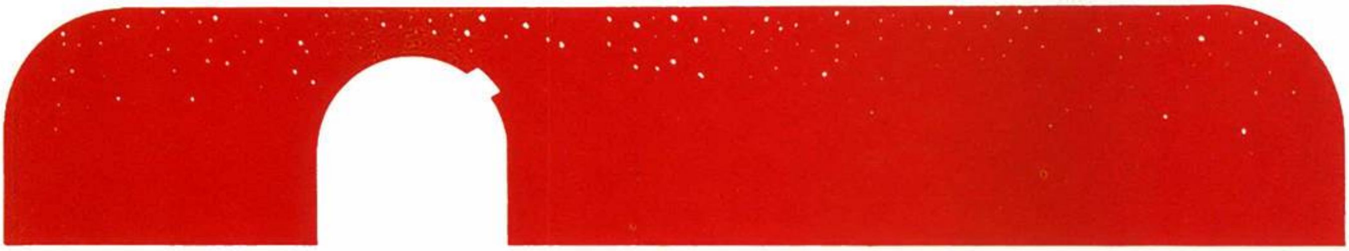
30

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.



PUBLISHER'S MEMO

Just a few things to say this month, so I'll be brief.

By now you've probably noticed that ASTRONOMY's editorial offices are no longer located at 757 N. Broadway. For the first three years of ASTRONOMY's existence, we were housed in an office building at the corner of N. Broadway and E. Mason Sts. in downtown Milwaukee. But we grew so much — so fast — that we no longer fit into the 1,400 square foot offices we had there. So, June 25, we picked ourselves up — lock, stock, desks and telescopes and moved two blocks down Mason St. (toward Lake Michigan) to beautiful, plush, new offices. With 5,000 square feet of office space, we now have room to move around comfortably and will be able to expand appropriately during the course of our new three year lease without being packed in like sardines.

We're so proud of our new offices that, if you're ever in Milwaukee, we invite you to stop in and say hello. I'm sure we'll be able to find someone who can take the time to show you around a bit too!

Henceforth, any mail going to Rosemary, Nancy, Pete, the editors, Dave, Penny or me should be addressed to us here at ASTRONOMY, 411 E. Mason St., 6th Floor, Milwaukee, Wisc. 53202. Incidentally, our telephone number remains unchanged and is still (414) 276-2689.

This month you'll notice that Star Dome has been moved and changed slightly. We've gone from two columns of type to three so we can include more meaty information each month. In addition, this department will always start on page 73 so you can easily turn to it first thing. Because it will be located in the last eight pages of the magazine each month, Star Dome can now be full color throughout. Finally, the Eyepiece Impressions subsection has been eliminated as a separate entity, but the information contained in it will be incorporated into Close-Up. We hope you like these changes, but regardless, please let us know what you think of the layout modifications.

From now on, when you submit photographs and slides to ASTRONOMY, it will no longer be necessary to send a stamped, self addressed return envelope. The return postage will be on us. However, **PLEASE, PLEASE, PLEASE** be absolutely certain your **complete name and full address is printed on each and every print and slide.** Even if you submit 50 to 75 slides at a crack — as some of our readers do — please include your name and address on each, because it's very easy for a slide to get separated from a submission. This not only helps guarantee that your photos will be properly returned if we don't use them, but also helps us serve you better.

So much for now. We'll talk to you again soon.

Sincerely,

Stephen A. Walther

Stephen A. Walther
Publisher

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When we say "performance," we mean, bluntly, the quality of the image you see or photograph through your telescope —be it binary stars, a moon detail or the rings of Saturn. If you look into the matter, you'll find facts to back up the following:

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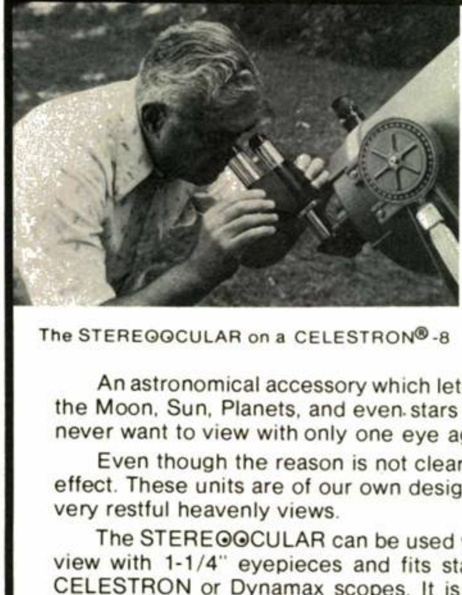

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STAR DOME

SEPTEMBER

by

James Mullaney and Henry J. Phillips

September sky watchers have a wide selection of suitable objects to choose from. For naked eye viewers, the summer triangle, almost at the zenith, dominates the sky, while the Great Square of Pegasus, rising in the east, brings promise of the autumn soon to come. The Milky Way can still be seen at its most glorious. If you concentrated last month's observation of the galaxy on the Sagittarius Starclouds near the southern horizon, September is a good month to move north and investigate the crowded star fields around Cygnus.

One notable aspect of September's stars is the flock of tiny constellations reaching the meridian, including Scutum, Sagitta, Vulpecula, Delphinus and Equuleus. No other area of the sky, with the exception of the south pole, contains so many constellations in such a small area. Some of these small groups are distinctive and easily found, while others require more careful search.

Just southeast of this crowded region lies Capricornus, one of the 12 constellations of the zodiac and (with the exception of Cancer) the faintest of them all. Capricornus is also the smallest of the 12 — smaller than Aries, whose I.A.U. boundaries cover a larger area even though it looks small.

Despite its faintness, however, Capricornus was an important group to the ancients. As with Leo, the group has a close association with the sun. It contained the winter solstice (the point on the ecliptic at which the sun reaches its lowest declination and winter begins) 3,000 years ago, and was known to the Chinese as the Southern Gate of the Sun. The early Greeks believed that, after death, the souls of men ascended to the heavens through its stars, and called the constellation the Gate of the Gods.

Once the sun reaches the winter solstice, of course, it begins climbing higher in the sky once again. It was probably for this reason that the stars of Capricornus came to be identified as a goat, for the wild goats of Europe and Asia were climbing animals that lived in mountainous regions. Most nations on these continents knew Capricornus as a goat or a goatlike animal; in parts of Asia it was an antelope, while even in modern Germany the group is called Steinbock, the ibex (a long-horned goat of the Alps).

But to the ancients, the sun's entrance into the stars of Capricornus held added significance, for it was at this time that the rainy season began. The following two zodiacal constellations — Aquarius the water bearer and Pisces the fishes — both depict watery subjects. Therefore, to make Capricornus conform to the pattern, it was metamorphosed into the sea-goat, an animal with the head and forequarters of a goat and the tail of a fish. It was thus known in Egypt, Babylonia and Syria. The Brahmin zodiac took this "fishification" one step further and made the group a whole fish. The Hindus called it Shi-Shu-Mara, the crocodile (another watery animal), but a few old Hindu references show a creature with the head of a goat and the body of a hippopotamus!

Today, we may prefer to see Capricornus as a goat since this representation would fit in well with the adjoining constellations. This entire area is a sort of barnyard in the sky, containing a goat, two horses, three birds, a fox and a dolphin — with an arrow, perhaps aimed by a clumsy hunter, thrown in for good measure.

The three birds are Cygnus the swan, Aquila the eagle, and Lyra, which today represents a lyre (or harp), but was almost universally known in ancient times as either another eagle or a vulture. Even 200 years ago the group was commonly known as Vultur Cadens, the swooping vulture.

Lyra was also once known as a turtledove, and this is where the figure of a lyre may have originated. If the name turtledove were rendered simply as "turtle", as it is in the Bible, the constellation might have come to signify that animal as it did to the ancient Romans and the Spanish. Since the first lyre was supposedly invented when the god Hermes stretched some strings across the empty shell of a turtle, the transformation becomes obvious.

Those who prefer a less fanciful — or less complicated — explanation for the change can simply point to the Greek name for the group's brightest star, Vega, which was Lura. A simple substitution of "y" for "u" gives us Lyra.

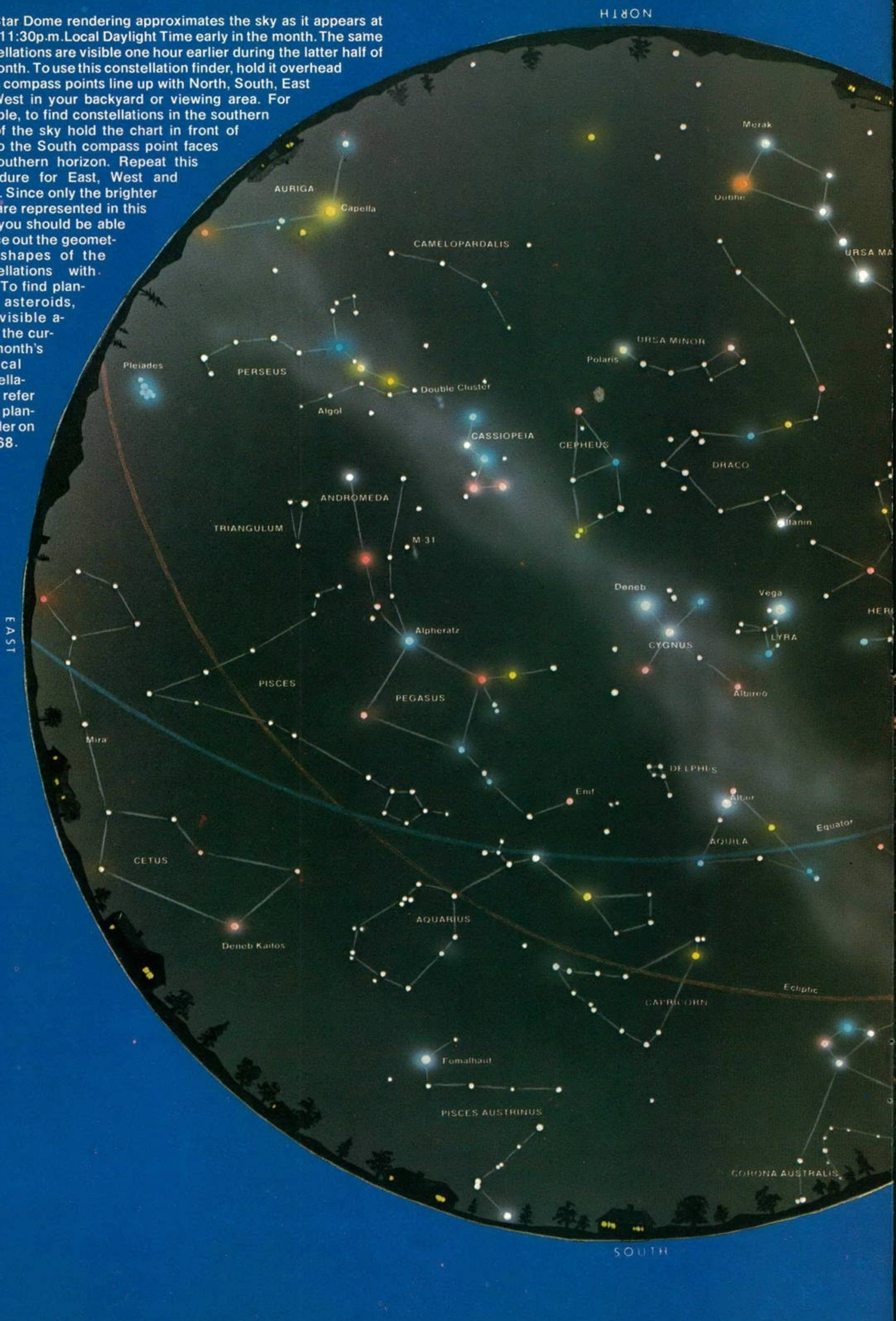
Between Cygnus and Aquila, the two surviving birds, lie three small constellations. The first of these, just north of Aquila, is Sagitta the arrow — a tiny but distinct group of four stars that (for once) really resembles what it is said to represent. Embedded in the Milky Way just east of the Great Rift, Sagitta provides excellent fields for sweeping with low power.

Nearby, and forming a triangle with Sagitta and Altair (brightest star in Aquila), is Delphinus the dolphin, swimming east of the Milky Way. This group has always had its present name — except to the English peasantry, who knew (and still know) Delphinus as "Job's Coffin", for reasons that are completely unknown.

Alpha and Beta Delphini have the odd names of Sualocin and Rotanev. These titles defied all attempts at analysis until the famous observer Webb thought to read them backwards, when they suddenly spelled out Nicolaus Venator — a Latinized version of the name Niccolo Cacciatore, who was an assistant to the Italian astronomer Piazzi, discoverer of Ceres. A cartographer acquaintance of Cacciatore's, wanting to honor his friend, supplied the two stars with his names, but spelled them backwards to make the honor less blatant. The names have stuck, and Cacciatore has achieved at least a form of immortality.

The third of the between-the-birds constellations is Vulpecula the fox. This is another invention of Hevelius', whose original name for the group was Vulpecula cum Anser, the fox and the

This Star Dome rendering approximates the sky as it appears at about 11:30p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page **68**.


NORTH
Merak
Dubhe
URSA MA
AURIGA
Capella
CAMELOPARDALIS
URSA MINOR
Polaris
Pleiades
PERSEUS
Double Cluster
Algol
CASSIOPEIA
CEPHEUS
DRACO
ANDROMEDA
TRIANGULUM
Eltanin
M 31
Deneb
Vega
HER
EAST
Alpheratz
LYRA
CYGNUS
PISCES
PEGASUS
Albireo
Mira
DELPHI S
Enif
Altair
Equator
AQUILA
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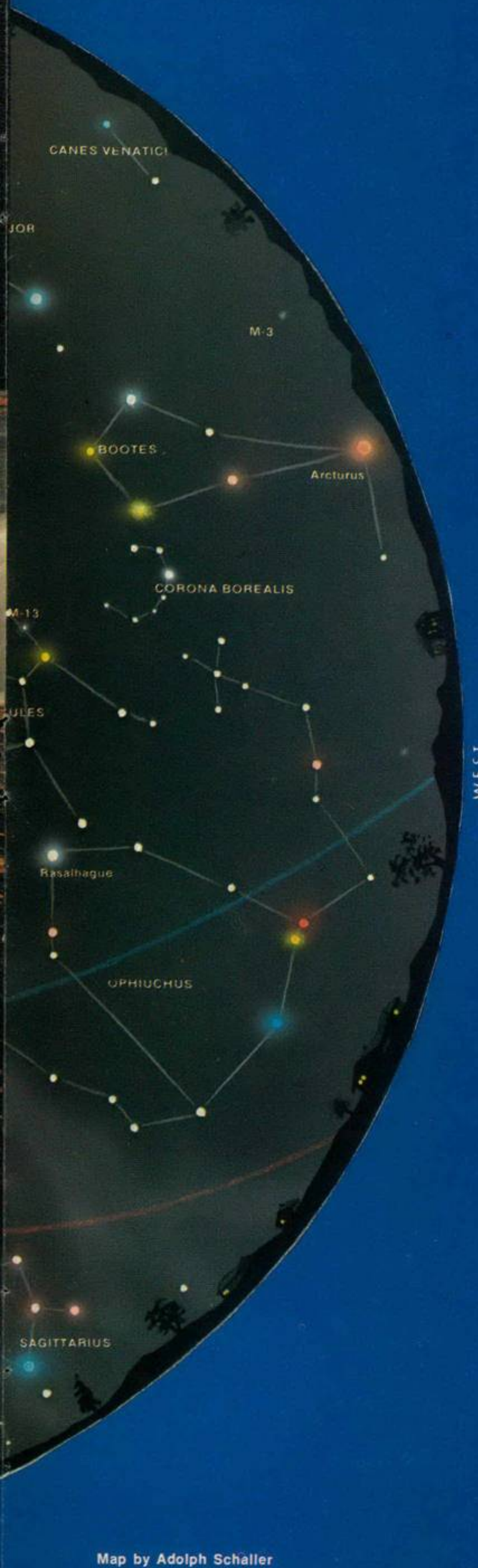


Map by Adolph Schaller
Centered on 40° N Latitude

goose. Hevelius wrote, "I wished to place a fox and a goose in the space of the sky well fitted to it; because (the fox) is very cunning, voracious and fierce. Aquila and Vultur are of the same nature, rapacious and greedy." Presumably the goose was meant to be a companion for the swan, but today it had completely disappeared except as the name of Alpha Vulpeculae; Anser. In any case, Vulpecula (like most of Hevelius' creations) is not very interesting to the naked eye, as it contains no star brighter than fourth magnitude. In fact, the group would be entirely unmemorable were it not for the presence within its borders of M-27, the famous Dumbbell nebula, brightest of the planetary nebulae.

Another little constellation lies east of Delphinus: Equuleus the colt. Equuleus is the second smallest of all our constellations, having an area only 72 square degrees. Only Crux, the Southern Cross, is smaller (and not by much). Equuleus is so tiny and inconspicuous that it's quite surprising to find it listed as a separate constellation by Ptolemy, in his writings around 200 A.D. Some have depicted a small colt prancing just short of the nose of Pegasus, its far larger equine companion to the east. Others have drawn only a horse's head. Harvard astronomer Donald Menzel prefers to see a sea horse in the constellation — certainly an appropriate notion, as it lies near Delphinus.

Finally we come to Aquila the eagle. Both the Greeks and Romans knew the constellation by this name, and both held the eagle in high esteem, considering it the companion of the gods. A Latin name for Aquila was Armiger Ales, the armor-bearing bird of Jupiter.

To the Greeks, the eagle was the bird of Zeus, and it carried messages to Earth when needed. The Norsemen thought of Aquila as a raven, and this bird served a similar function to the chief god, Odin. Two ravens named Hugin and Munin (thought and memory) flew into the world each day, returning to Valhalla, home of the gods, at night to whisper to Odin of the deeds of men.

Aquila today is larger than it was long ago, for originally only Altair and the stars on either side of it were thought to represent the eagle and its outstretched wings. These two stars are named Alshain (Beta) and Tarazed (Gamma). Both names are derived from the Persian title for Aquila: Shahin tara zed, the star-striking falcon. Iota and Lambda Aquilae are together known as Al Thalimain, which means two ostriches. How these two birds happened to wander into this part of the sky is unknown.

The pattern of stars in Aquila is actually not very prominent, but we can imagine Altair and its companions marking the head, with Zeta and Theta being the wings and Lambda the tip of the tail. With the eagle flying north in this fashion, we are presented with the startling prospect of the eagle about to collide head-on with the southbound swan!

Close-Up

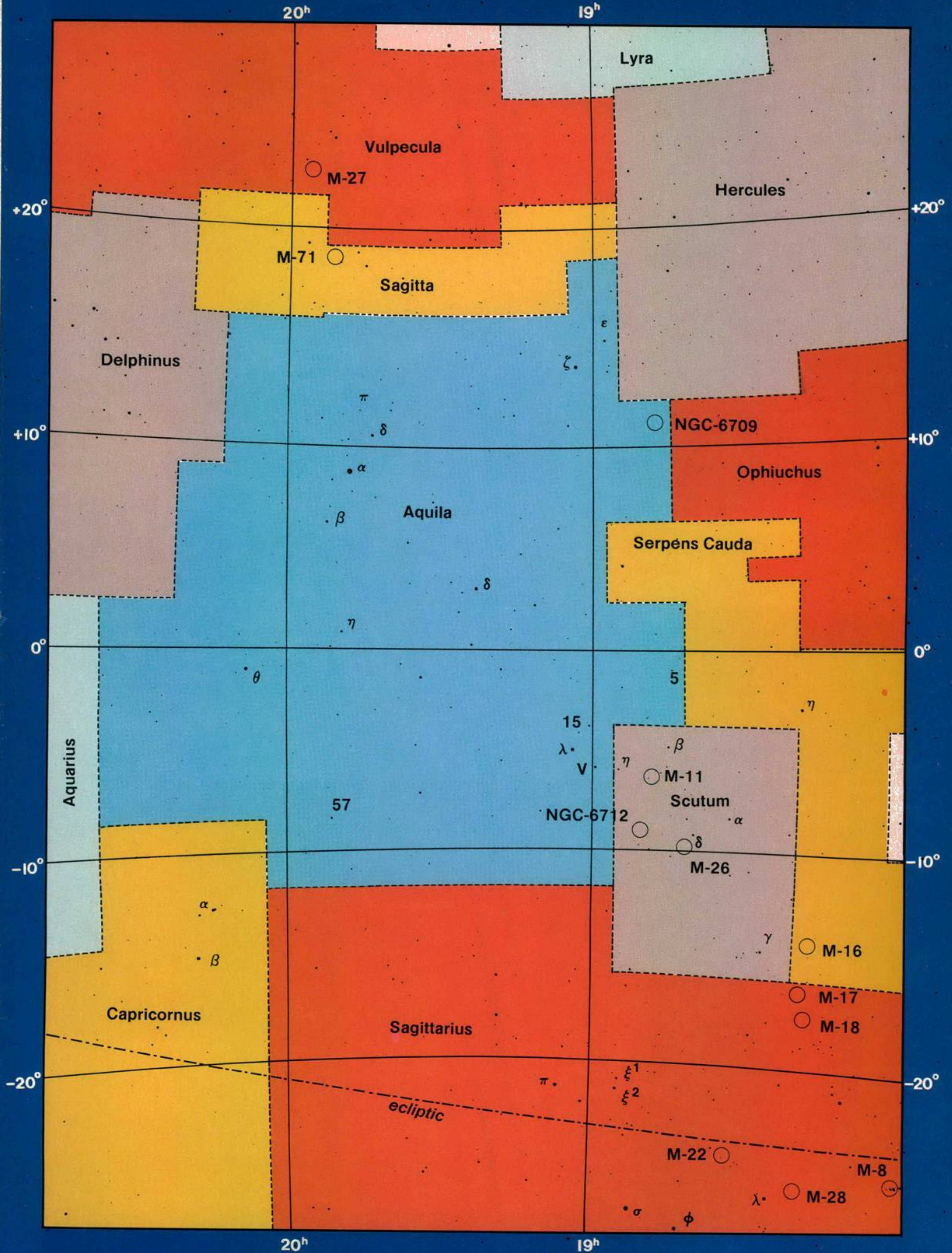
Aquila/Scutum Region

The adjoining constellations of Aquila and Scutum, lying near the southern meridian on early September evenings, are well situated for study at this time. The latter group is tucked beneath the southwest corner of the former and is so small that some authorities of the past considered it a mere asterism rather than a full-fledged constellation.

Scutum once covered a more extensive area than it does today. The constellation boundaries that were officially adopted by the I.A.U. in 1930 greatly reduced its area, causing it to lose such deep sky showpieces as M-16, M-17, M-18 and M-24 (now located in Sagittarius or Serpens Cauda). Enough remains, however, to offer magnificent sweeping for binocular users — especially the Scutum Starcloud which contains the cluster M-11. On a good night, the Milky Way in Scutum might almost be mistaken for terrestrial clouds!

Sweeping the Aquila/Scutum region with low power, wide field instruments such as richest field telescopes will reveal many apparent "clusters" of stars where none are shown in atlases. These areas are simply concentrations in the endless strata of stars along the plane of our galaxy. Webb tells us that this part of the heavens is "full of splendid telescopic fields and the very ground of the Milky Way seems here resolvable."

Aquila itself is surprisingly empty of the prominent nebulae and clusters found elsewhere along the summer Milky Way. The constellation's main visual attraction is blue-white lucida — Altair, the southern member of the famous summer triangle. Altair's name means "flying eagle"; as Barns points out, it is "central of three stars representing an eagle in flight — one of the few skiey similitudes that seems to be even remotely justified." Altair's two companions are Beta to the southeast and Gamma to the northwest. The three form a line five degrees long and provide a convenient yardstick for this part of the sky.

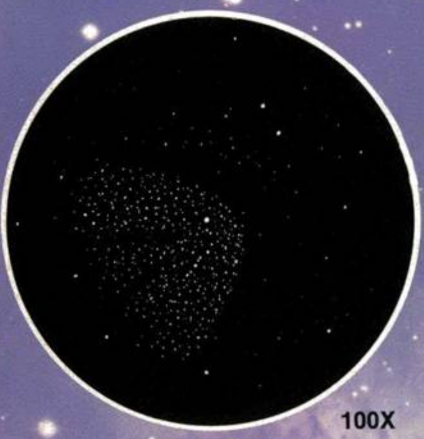

20h
19h
+20°
+10°
0°
-10°
-20°
Lyra
Vulpecula
M-27
Hercules
M-71
Sagitta
Delphinus
ε
ζ
π
δ
NGC-6709
α
Ophiuchus
β
Aquila
Serpens Cauda
δ
η
θ
5
η
15
λ
β
V
η
M-11
Aquarius
Scutum
57
NGC-6712
α
δ
M-26
α
γ
M-16
β
M-17
Capricornus
Sagittarius
M-18
ξ1
π
ξ2
ecliptic
M-22
M-8
λ
M-28
σ
φ

Photograph by Brad Wallis and Robert Provin/Map by Victor Costanzo

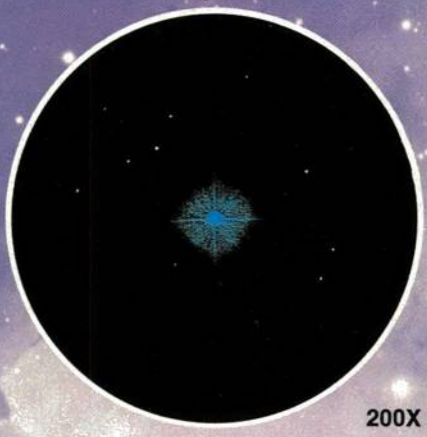
Putting this measure to use, look five degrees directly south of Altair to the star Eta Aquilae. This is an easily observed Cepheid variable star whose brightness varies between magnitudes 3.7 and 4.7 over a period of seven days. A good comparison star is Beta, shining at a constant 3.9 magnitude; at its maximum, Eta slightly outshines Beta, while at minimum, Eta is noticeably fainter.

Speaking of variable stars, the most exotic and spectacular members of this class are the novae or exploding stars. The Milky Way is so dense in this month's region that a considerable number of these objects have appeared here. One of the first recorded novae erupted near Altair in 389 A.D.; it became as bright as Venus and then vanished in three weeks. Another spectacular explosion occurred in June 1918, when a nova near Aquila's western border became brighter than Altair. In fact, Nova Aquilae 1918 has been the brightest nova of the 20th century thus far; at magnitude -1.1, it outshone every star except Sirius.

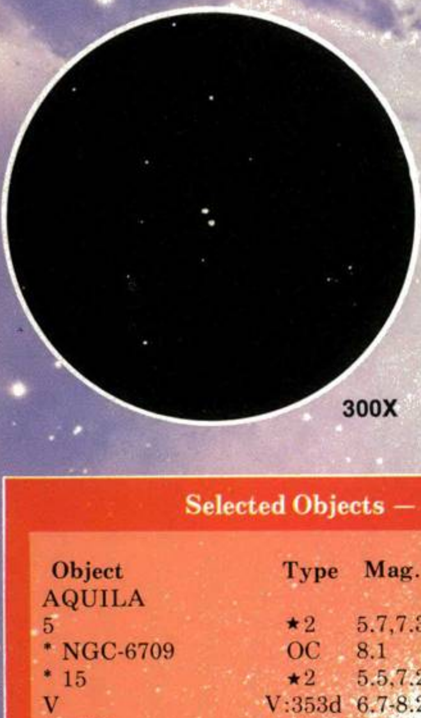
M11



15 Aquilae



Altair



Top left: M-11 appears as a round glow in binoculars, but with an eight inch reflector at 100 power, it's resolved into hundreds of stars. While most galactic clusters have a wide range of brightness among the stars, M-11 gives the visual impression of having many stars of nearly the same brightness. Top right: In a four inch reflector, its contrasting colors and wide separation make 15 Aquilae a pleasing object to show friends and relatives — especially on those nights when the moon blots out deep sky objects. Left: Bright stars like Altair are a splendid sight in a telescope of medium size, such as a six inch reflector. Their color stands out vividly: Altair is blue-white compared to Vega's blue or Acturus' ruddy hue. Drawings by James Mullaney.

Selected Objects — Aquila/Scutum Region

Object	Type	Mag.	Size/ Sep.	R.A. (1950)	Dec.
AQUILA					
5	★2	5.7,7.3	13"	18^h44^m	-01°01'
* NGC-6709	OC	8.1	12'	18^h49^m	+10°17'
* 15	★2	5.5,7.2	38"	19^h02^m	-04°06'
V	V:353d	6.7-8.2	—	19^h02^m	-05°46'
* π (Pi)	★2	6.2,6.8	1.5"	19^h46^m	+11°41'
* Altair		0.8	—	19^h48^m	+08°44'
* 57	★2	5.8,6.5	36"	19^h52^m	-08°22'
SCUTUM					
* M-26	OC	9.3	9'	18^h42^m	-09°27'
* M-11	OC	6.3	10'	18^h48^m	-06°20'
* NGC-6712	GC	8.9	2'	18^h50^m	-08°47'

* Detailed in Close –Up

★2 = Double Star
OC = Open Cluster
GC = Globular Cluster
V:#d = Variable Star, period (days)
Mag. = Magnitude
Sep. = Separation

These unannounced apparitions have been so frequent in this area that they have come almost on top of each other — as in 1943 and again in 1945. There were even two in the same year (1936)!

The majority of these temporary stars have peaked in magnitude just near naked eye visibility, and are hardly noticeable to the casual stargazer. Nevertheless, nightly nova searches with the eye and binoculars in the Aquila/Scutum region could yield dividends to the perservering observer. A good atlas and thorough familiarity with the existing star patterns down to at least sixth magnitude are a must for such watches. Even if you don't find novae, you'll soon become well acquainted with a rich section of the summer sky.

Altair

Although usually passed over by telescopic observers, 0.8 magnitude Altair [Alpha (α) Aquilae] deserves attention. Its chief attraction is its lovely blue-white hue — at least, most eyes see it as such. Barns called this gem white, and Olcott, yellow. Menzel considers stars of Altair's spectral class (type A) as green. What do your eyes and telescope show — white, blue, green or yellow?

The Altair field contains a number of faint background stars that form optical companions to the great star and provide a fine magnitude contrast in four inch and larger scopes, as shown in our drawing.

Strangely, neither Barns nor Webb mention these field stars, and Olcott lists only one of them — a 10th magnitude object at a separation of 152 seconds of arc. Webb does tell us, however, that "All the galaxy here is strewed with pairs and groups of stars." Low power sweeping in the vicinity of Altair will turn up many of these.

This beautiful star lies just 17 light-years from us, against the backdrop of the summer Milky Way. Approaching us at the rate of 16 miles per second, it is intrinsically some 10 times as luminous as our sun.

NGC-6709

Typical of the many star gatherings scattered throughout this month's region is the open cluster NGC-6709, most easily found by setting your telescope on Gamma (γ) Aquilae and sweeping 14 degrees (or 55 minutes of right ascension) due west. A good finder will readily show it near that position. A three or four inch telescope at 45 power reveals an irregular shaped splash of mixed bright and faint stars in the 9th to 12th magnitude range. An apparent triple star stands out near one edge of the cluster.

This group has an integrated (combined) brightness equal to an eighth magnitude star, but the light is spread over an area about 1/2 the moon's diameter. Both Webb and Olcott call NGC-6709 a beautiful object, while Barns puzzles us with his description: "Two clusters. Alluring expanse follows." Do you see two clusters here, or one?

Pi (π) Aquilae

The Aquila/Scutum region is loaded with many fine double and multiple star systems within the reach of small telescopes. One of the more challenging of these is sixth magnitude Pi Aquilae, situated just 1-1/2 degrees northeast of Gamma. This duo consists of 6.2 and 6.8 magnitude suns, a close 1.5 seconds apart. A four inch splits them nicely at 150 power; if the eyepiece has sufficient field, a nearby star of sixth magnitude can be included, making Pi an apparent triple.

All three objects look yellowish white but there has been great divergence in the colors reported by various observers over the years. The close pair is given as yellow and green by Webb, pale white and greenish by Smyth and yellow and blue by Secchi. Reddish white and azure have also been seen.

Webb, using his 3.7 inch refractor, noted "not single 80 (power), very close 144, good test". Barns sums up this object nicely as a "color-test".

15 Aquilae

A much easier double for small instruments is offered by the fifth magnitude star 15 Aquilae, one degree north and slightly west of Lambda (λ). Here we find 5.5 and 7.2 magnitude components an easy 38 seconds distant. A 2.4 inch refractor at 30 power splits them pleasingly, while a four inch reflector at 50 power presents an excellent color contrast of yellow and reddish purple, as shown in our drawing.

Olcott saw these stars as white and lilac. Webb on different nights listed them as white (or yellowish-white) and red lilac, and yellowish and ruddy purple. All of these observations are in agreement, indicating the tints are definite. Barns does not mention colors for this double but describes the stars as "Gems in a royal crown." While no match for bright pairs like Albireo in nearby Cygnus, 15 Aquilae is still a crowd pleaser at the telescope.

57 Aquilae

Another fine double — but one in which the colors are not obvious — is another fifth magnitude star, 57 Aquilae, located 17 degrees due south of Altair. A line from Altair through Eta (η) extended slightly more than its length points directly at it. A sixth magnitude neighbor shines nearby.

The components this time are of 5.8 and 6.5 magnitudes, a roomy 36 seconds apart. Here, too, the smallest telescopes will easily show the two stars, but this time the hues are quite subtle. The eye can sense the presence of color, but pinning it down to exact shades is difficult — so much so that Barns simply dubbed this pair "a color variant".

Among the tints reported are yellow and green, both bluish and both greenish. Webb conveys the situation well: "Distinctly contrasted 1851, pale yellow, pale lilac; colors entirely different, 1855 . . . pale yellow, bluish or greenish; certainly unlike nine inch (reflector), 1871 . . . Should be watched . . . ."

The best aperture for performing a color check on 57 is in the four to eight inch range; in this case, anything smaller does not deliver enough light to the eye for good color perception, while anything larger overwhelms it. Every telescope has a large class of double stars for which its aperture is uniquely suited for studying colors (and resolution).

Perhaps the most apt description of this duo's present appearance is "both greenish/blue-white". Do you agree?

M-11

Our survey of this stellar wonderland concludes with one of the finest open clusters visible from northern latitudes. This is M-11, a misty patch of light barely visible to the unaided eye, found just west of the star chain formed by Lambda Aquilae, 12 Aquilae and Eta Scuti.

This object presents a glorious sight in every type of instrument and is one of the few members of its class that has a striking appearance in observatory telescopes, with their typically high magnifications and small fields. Medium powers work best — 90 power on a four inch breaks M-11 into a beautiful splash of stardust, while the view in 8 to 12 inch scopes is simply breathtaking, as our drawing can only hint.

M-11 appears as a rich, compact, uniform glow of more than 200 stars some 10 minutes of arc in extent. Its shape is asymmetrical, and it has an eighth magnitude star located within its apex. Nearly all observers agree in calling it fan shaped, while Admiral Smyth likened its appearance to a flight of wild ducks — hence the name sometimes encountered of "Wild Duck nebula". Both terms fit perfectly.

Herschel called attention to M-11's seeming arrangement into five or six groups of stars. Many observers have reported dark structures or rifts within the cluster; these areas devoid of stars may be an illusion caused by star chains, or they may be actual obscuring lanes of dust. In 10 and 12 inch telescopes, they seem darker than the softly glowing sky background outside the cluster itself.

The occurrence of bright nuclear stars, dark gaps and star chains in open clusters is a frequent sight to the attentive visual observer. Unfortunately, little attention has been given these features by professional astronomers — perhaps because they are often lost on time exposure observatory photos.

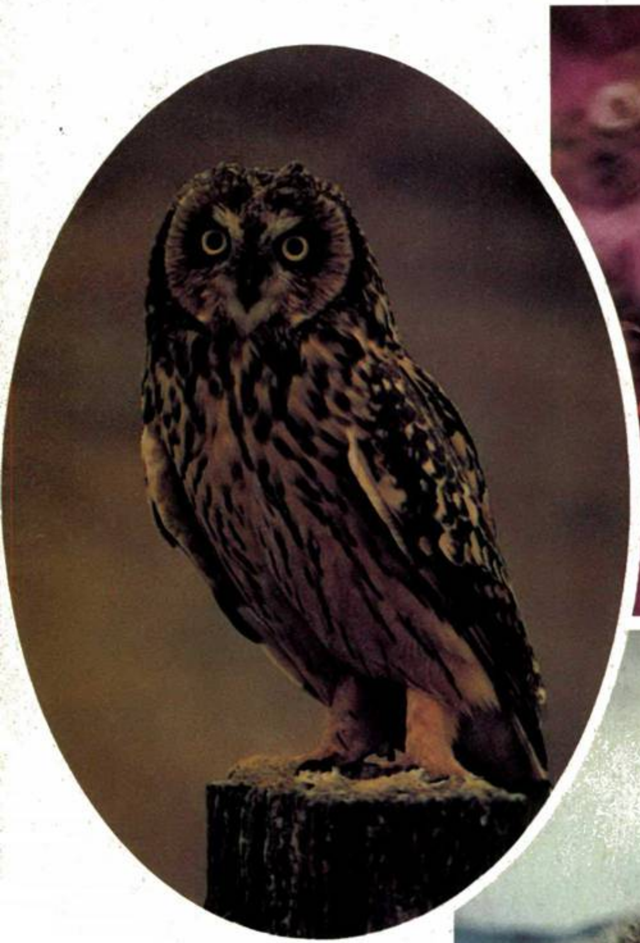
M-11 is considered something of an oddball among the family of star clusters. It is much too rich to fall into the "normal" open cluster grouping, but at the same time too sparse to be a globular. Thus, it is sometimes classed as semiglobular — perhaps bridging the gap between the two types. Indeed, time exposure photographs lasting more than a few minutes destroy the visual shape completely, revealing M-11 as a typical globular cluster. An interesting project for those who enjoy skyshooting would be to show the changing aspect of this object with increasing exposure time.

Scutum provides us with convenient examples of both open and globular clusters for comparison with M-11. M-26 is situated a degree southeast of Delta (δ) Scuti and consists of a ninth magnitude irregular glow of some 20 stars in an area nine minutes of arc across. Its visual appearance as a sparse open cluster is quite unlike that of M-11.

Just 2-1/2 degrees south of M-11 is the ninth magnitude globular cluster NGC-6712, appearing as a misty granular patch of light only two minutes in diameter. Again, it looks nothing like M-11. Both M-26 and NGC-6712 are well seen in four inch and larger instruments. Why not run your own comparison test the next dark clear night?

We view this glittering stellar commune buried amidst the summer Milky Way, from a distance of more than 4,000 light-years. Seeing M-11 and the immense star clouds of which it is a part, we may be reminded of the closing lines of Arthur Clarke's classic short story, **The Sentinel**: "I can never look now at the Milky Way without wondering from which of those banked clouds of stars the emissaries are coming. If you will pardon so commonplace a simile, we have set off the fire-alarm and have nothing to do but to wait. I do not think we will have to wait for long."

Considering the varied scenes we have just explored, along with recent attempts at interstellar communication, these lines of fiction written 25 years ago seem even more prophetic today.



CLOCKWISE FROM ABOVE:

Owl at 20 feet
Celestron 750mm, f/6

Rose at 15 feet
Celestron 750mm, f/6

Peacock at 50 feet
Celestron 750mm, f/6

Orion Nebula
Celestron 8

Rings of Saturn
Celestron 14

Squirrel at 75 feet
Celestron 1250mm, f/10

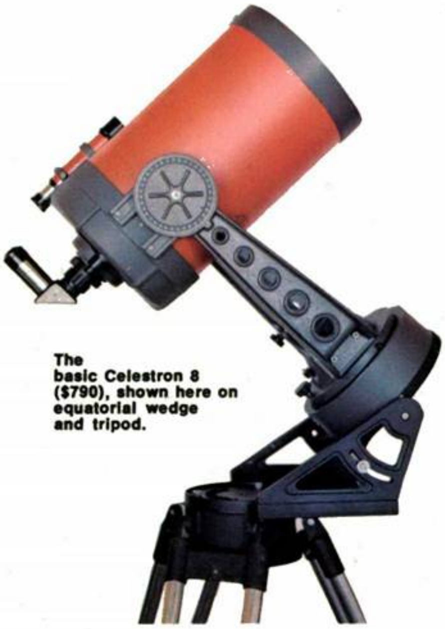
We Give You New Worlds

Beyond the front end of a Celestron Telescope lie entirely new worlds — bigger, brighter, sharper, more detailed worlds.

Our sunlit Earth — marvelous in its intricacy, overwhelming in its color, profound in its immediacy. And worlds beyond — in a universe of majestic proportions and breathtaking beauty. A universe where planets roam the outer reaches of our solar system and their moons shuttle to and fro. Where great spheres of stars — light-centuries in diameter — ride loftily above the disk of our galaxy. Where remote clouds of gases cast their eerie filamentary glow onto the waters of infinity.

These are the worlds we offer.

And next week at this time, you could have in your hands the means to explore them.



The basic Celestron 8 ($790), shown here on equatorial wedge and tripod.

For a closer look at the worlds we offer, send for our free color catalog.
Write to Celestron International,
2835 Columbia St., Box 3578-AM,
Torrance, Calif. 90503, USA.
Or telephone (213) 328-9560.

Celestron

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